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目　次

現行水稻推廣品種生產力與氮肥用量之關係

II.氮肥用量對稻米容重及品質之影響……　賴明信　陳正昌　陳治官　曾東海　郭益全　李長沛　林英俊… 1

白米食用與加工品質性狀之 Griffing 與

Hayman 氏全互交變方分析(英文)　……　郭益全　偉伯比爾　史譚索詹姆士…15

仙草品系間農藝性狀與化學組成分之比較 …　胡敏夫　劉慧瑛　朱鐵良　劉新裕…32

低需冷量桃樹果實發育所需的熱量時間 ………………………　宋家瑋　歐錫坤…42

不同樹種來源單獨與混合木屑對杏鮑菇瓶栽生產影響之研究

………………………………………………………………………………………………　彭金騰…51

廢棄菇類木屑堆肥應用於洋香瓜育苗介質之評估

………………………………………………………………………　張明暉　向為民　簡宣裕　黃維廷…60

廢棄香菇木屑堆肥研製及對小白菜之肥效 ……………………　簡宣裕　莊作權…70

應用非線性迴歸方法於土壤吸附重金屬動態

反應模式之參數設定 ……………………………………………　劉滄棽　林正錺…82

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現行水稻推廣品種生產力與氮肥用量之關係

II.氮肥用量對稻米容重及品質之影響[1]

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摘要：爲探討臺灣水稻推廣品種於不同氮肥用量下稻穀容重、糙米容重、碾米品質及白米物理與化學特性之變化，本試驗以四個水稻品種臺農67號、臺稉 2 號、臺稉 6 號及臺中秈10號爲材料，第一期作施以60、100、140、180 kg N/ha，第二期作施以60、90、120、150 kg N/ha 等四個氮肥處理，於1993及1994年在農試所農場連續進行兩年四期作之田間試驗。結果顯示：第一期作參試三個稉稻品種之稻穀容重及完整米率與施氮量呈直線關係，均隨氮肥施量之增加而降低。臺中秈10號之稻穀容重及完整米率與施氮量分別呈二次及三次曲線關係。而四個參試品種之直鏈澱粉含量及粗蛋白質含量與氮肥施量皆呈直線關係，其中，直鏈澱粉含量隨氮肥施量之增加而減少，但粗蛋白質含量則隨氮肥施量之增加而增高。第二期作四個參試品種之稻穀容重除臺稉 2 號外，均隨氮肥施量之增加而減少，完整米率及直鏈性澱粉含量與氮肥施量具有線性關係，粗蛋白質含量隨氮肥施量之增加而增加。綜合兩年四期作之資料指出，降低氮肥用量可提高參試稉稻之稻穀容重但降低粗蛋白質含量，而對完整米率與直鏈性澱粉含量之影響因期作而有差異。考量本試驗稻穀產量與稻米品質之資料認爲較佳的氮肥施用量，第一期以不超過140 kg N/ha，第二期作以90 kg N/ha 爲最適當，增加氮肥用量對稻米品質有負面的影響。

關鍵詞：水稻、氮肥、稻穀容重、糙米容重、稻米品質。

稻米品質係綜合米粒各種理化性質而成之一種複合性狀，一般被歸納成碾米品質、米粒外貌及烹調與食用品質等三大類。此三構成要素主要取決於品種本身之遺傳特性，但產地、成熟期間之溫度與日照及栽培管理等環境因素的影響尤爲顯著。郭等(8)即指出期作及地區均會影響稻米之碾米品質及其理化性質。大體上，地區環境包含了土壤質地、成熟期間之溫差及施肥法等，其中僅施肥法可經由人爲栽培手段控制。衆所週知，氮素是水稻生產所需元素中最重要者，增施氮肥雖然對稻穀生產貢獻很大，於一定的氮肥用量下，稻穀產量隨施氮量增加而增加，但報告指出富含腐植質或氮土壤所生產之稻米，及產自黏重土壤或生長過度繁茂或倒伏稻株之稻米，品質往往欠佳(14)，而且氮肥施用過量或施用時期不當，穀粒發育會停止，導致死米及乳白米的增加(4)，著色米及斑點米亦會增加(21)。於施用方式上，氮肥一半當基肥另一半當追肥在幼穗分化期施用，其完整米率較一次施用有顯著提高(24)；但品種不同受影響之程度亦不同。一般而言，米粒外觀差者施氮量與米質間無一定趨勢，米粒外觀佳者施氮量愈少米質愈好(9)；而且施氮量對稻米之糙米率、白米率及完整米率有正面的貢獻(1)。

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概略而言，影響稻米烹調及食用的理化性質主要因素爲糊化溫度、直鏈性澱粉含量、膠體性質及蛋白質含量。此四種因素雖主要決定於品種本身之遺傳特性，但蛋白質含量及直鏈性澱粉含量受栽培環境影響甚大。郭[6]指出氮肥用量與施用時期、農業化學藥劑之類別與施用、栽培地區、季節年代日照、水分管理、栽培密度及收穫時期等皆爲顯著影響米粒蛋白質含量變化較爲已知的大環境。許及宋[11]亦指出蛋白質含量低、直鏈性澱粉含量低、膠體軟硬度較高之稻米，其口感較佳。Juliano[19]指出米粒蛋白質含量之變異隨氮肥用量之增加而增大。很多研究報告亦顯示，米粒蛋白質含量隨著氮肥用量增加而相對增加[15,16,17,23]，而且分施比全量基肥施用可得較高的米粒蛋白質含量[15,24]；而施用時期不同粗蛋白質含量亦有變化，抽穗期施用比幼穗分化期施用有較高蛋白質[15]，在成熟期施用將導致植株及穀粒氮素含量增高，若在齊穗期施用氮素3～9g/m，可提高穀粒氮素含量達11～25%[22]。蛋白質含量高低與稻米食味品質有密切關係；相同品種在固定水量下煮飯時，蛋白質含量較高者其米飯較易破碎成片[11]，其米粒較硬、煮飯時之黏性較差及色澤較呈褐色[20]；具體而言，當糙米含氮量超過1.5%或白米蛋白質含量超過 9 %時，食味品質有惡化現象[28]。洪[5]指出穀粒之蛋白質主要散佈在糠層及表層，低蛋白質含量的米可減少煮飯時水進入米粒內部的阻力，而讓米飯易完全均勻的糊化，入口品質會較佳。許及宋[10]亦指出施用穗肥之處理所生產之稻穀其蛋白質之含量較多，以 Texturemeter 測得之硬度數值較大，而Yamashita[27]先前即指出在齊穗期施用氮肥，尤其是在幼穗形成期已施用穗肥者，會降低米飯之食味品質。

雖然環境影響米粒之直鏈性澱粉含量的方式不很清楚[18]，但一般稻穀成熟期間外界之氣溫被認爲是影響直鏈性澱粉含量之主要因素；平均氣溫升高，直鏈性澱粉含量降低，但秈稉兩型之反應不一致，而氮肥之增施會導致直鏈性澱粉含量略微降低，施用時期不同則無影響[24]，郭等[7]亦指出品種間及栽培地點間直鏈性澱粉含量之差異顯著。

綜上可知，有關氮肥對複合性狀稻米品質之影響的研究多且詳細，但生產優良品質白米之前提乃需有優良稻穀，而有關氮肥對稻穀容重影響之報告很少。宋等[2]即指出二期作生產之稻穀容積重較第一期作重。而經濟部中央標準局業已就稻穀、糙米及白米分別訂定國家標準，並規定未來生產良質米的稻穀，必須先符合國家標準，影響所及是將來分級收購制度落實以後，稻穀的品質對稻農之所得會有深巨的影響。基此本文擬探討施氮量對稻穀及稻米品質之影響，以供田間栽培管理之參考。

材料與方法

以現行主要推廣品種臺農67號、臺稉 2 號、臺稉 6 號及臺中秈10號等四個品種爲材料，分別於1993及1994年二月中旬及七月下旬於臺灣省農業試驗所農場各揷植一次，計兩年四個期作。試驗田區採裂區設計，以氮肥爲主區，參試品種爲副區，三重複。每小區種植八行，每行揷植32株，4～6 本植，行株距30×15公分。肥料主區均以田埂分隔，並有各自之灌排系統，同時氮肥主區每年皆固定，惟主區內之品種每年逢機排列。

田間氮肥處理分爲四個等級，分別爲第一期60、100、140及180kg/ha，第二期作60、90、120、及150kg/ha。全氮之30%與72kg/ha之磷肥及48kg/ha的鉀肥混合於整地前當作基肥一次施用。全氮之55%於揷植後15天及35天分兩次施用，15%則於幼穗形成期時以穗肥施用。田間管理依普通慣行方法施行，病蟲害防治。以22 .55%陶斯松乳劑（1.8L/ha）、45%一品松乳劑（1.0L/ha）、25%歐殺松乳劑（2.0L/ha）、及25%布芬淨粉劑（0.8kg/ha）混合施用，稀釋500倍，一期作於移植後50天及74天，二期作則於22天及52天各噴施一次。成熟適期，每小區逢機收穫10m²置於乾燥箱中一致調製後調查分析品質性狀，包括稻穀容重、糙米容重、碾糙率、碾白率、完整米率以及直鏈性澱粉含量、粗蛋白質含量與膠體軟硬度等八項。而碾米品質項目之測定係參考 Webb *et al.*[25]、Webb[26]及Barber and Barber[13]之標準進行，理化性質則在臺中區農業改良場米質研究室分析。

結　果

一、綜合變方分析

表1爲合併兩年的第一、二期作之稻穀容重、糙米容重、碾米品質及理化性質之綜合變方分析。結果顯示第一期作之稻穀容重、完整米率、直鏈性澱粉含量、粗蛋白質含量及膠體性質對氮肥處理均呈現顯著差異，而糙米容重、糙米率及白米率在氮肥處理間則差異不顯著。所有性狀於不同品種間皆呈極顯著差異。除粗蛋白質之品種與氮肥間交感效應不顯著外，稻穀容重、白米率、完整米率及膠體性質、糙米容重、糙米率及直鏈澱粉含量則呈顯著交感效應，顯示該等性狀因品種不同對氮肥之反應有差異。第二期作之稻穀容重、糙米容重及粗蛋白質含量對氮肥處理呈顯著差異，其他性狀則不呈顯著差異。不同品種間之所有性狀皆呈顯著差異，此結果與第一期作相同。除糙米容重之品種與氮肥處理的交感呈顯著外，其他性狀之品種與氮肥處理的交感效應不顯著，顯示這些性狀對氮肥處理之反應不因品種不同而異。

表 1. 稻米品質性狀之變方分析

Table 1. Analysis of variance for milling quality, physicochemical properties and volume weights of paddy and brown rice.

S. O. V.	DF	Mean Square							
		volume wt. of paddy rice	volume wt. of brown rice	brown rice rate	milled rice rate	head rice rate	amylose content	crude protein content	gel consistency
1st rice crop									
Year(Y)	1	1,617.04*	96.00	0.55	4.55*	179.85**	148.75**	50.56**	2,161.25**
Block/year	4	123.67*	84.45**	0.20	0.23	8.46**	0.55*	0.12*	13.74
Nitrogen(N)	3	2,336.08**	39.58	0.09	0.65	7.95*	5.80**	8.25**	92.61**
Y×N	3	186.40	50.41	1.27**	0.82	20.51**	2.20*	0.98**	152.84**
N×Block/year	12	62.98	22.66	0.10	0.27	1.51	0.38*	0.10**	15.04*
Variety(V)	3	357.25**	3,217.91**	62.81**	48.87**	89.33**	8.20**	0.64**	103.36**
Y×V	3	234.12**	78.41**	0.08	0.13	21.69**	11.02**	0.02	16.73*
V×N	9	161.11**	35.22*	0.32*	0.75**	35.40**	0.44*	0.02	22.29**
Y×V×N	9	30.44	23.09	0.11	0.17	19.77**	0.82**	0.03	19.79**
Error	48	42.85	15.08	0.12	0.25	1.75	0.19	0.03	5.98
2nd rice crop									
Year(Y)	1	1,001.04*	1,357.51**	5.36**	0.58	2.37	2.50	30.11**	14,889.70**
Block/year	4	66.63	7.44	0.25	0.34	2.70*	13.69**	0.11	110.94**
Nitrogen(N)	3	512.41**	11.48*	0.25	0.27	1.08	0.67	4.63**	14.96
Y×N	3	34.51	31.28	0.32	0.29	1.73	1.46	0.04	10.35
N×Block/year	12	35.37	11.23	0.21	0.36	0.94	0.51**	0.07	25.51
Variety(V)	3	1,969.86**	4,301.01**	76.60**	78.56**	56.16**	2.06**	2.04**	390.20**
Y×V	3	551.01**	18.37	0.70*	3.35**	9.01**	2.33**	0.23	1.49
V×N	9	36.81	31.43*	0.15	0.18	1.00	0.21	0.04	6.81
Y×V×N	9	23.26	29.55*	0.21	0.26	0.54	0.31	0.14	33.99
Error	48	28.24	12.26	0.24	0.24	0.79	0.16	0.11	18.37

*,** significant at 0.05 and 0.01 probability levels, respectively.

二、施氮量對稻米品質之影響

爲瞭解施氮量對各性狀之影響，進一步就各別品種之性狀於不同氮肥用量處理下的反應進行分析，表 2 爲第一、二期作各品種之稻穀容重、糙米容重及稻米品質於不同施氮量的反應。由表顯示第一期作稻穀容重隨施氮量增加而減輕，除臺農67號於施氮量100kg/ha時明顯高於140kg/ha 時外，其他品種之上述兩處理間差異不顯著，除臺稉 2 號外都明顯高於施氮量180kg/ha之處理。糙米容重於臺稉 2 號及臺中秈10號施氮量間差異不顯著，而臺農67號及臺稉 6 號則隨施氮量增加而減少，以施氮量60kg/ha 時所得最高，明顯高於施氮量180kg/ha。糙米率在臺稉 2 、 6 號施氮量間差異不顯著，臺農67號在施氮量100kg/ha時最高，臺中秈號於施氮量180kg/ha時最高。白米率在臺稉 6 號施氮量間差異不顯著，臺農67號及臺稉 2 號在施氮量140kg/ha以下的處理差異不顯著，但皆高於施氮量180kg/ha，而臺中秈10號在施氮量140kg/ha以上的處理差異不顯著，但高於施氮量100kg/ha以下之處理。完整米率之差異因品種及施氮量之反應走勢不相同，臺農67號隨施氮量增加遞減，臺稉 2 、 6 號於施氮量100kg/ha時最高，施氮量140kg/ha以上之處理差異不顯著，臺中秈10號在施氮量140kg/ha以上表現明顯較佳。直鍊性澱粉含量於所有參試品種在100kg/ha以下之處理明顯高於140kg/ha以上之處理，參試稉型品種以施氮量100kg/ha時最高，臺中秈10號以在施氮量60kg/ha時最高。粗蛋白質含量隨施氮量增加而增加，施氮量140kg/ha以上之處理明顯高於施氮量100kg/ha以下之處理，而且當施氮量由140kg/ha增加至180kg/ha時，臺農67號及臺中秈10號於180kg/ha之粗蛋白質含量明顯提高。膠體性質受施氮量影響，除臺稉 2 號在氮肥處理間差異不顯著外，其他品種在施氮量100kg/ha以下之處理明顯高於施氮量180kg/ha之處理。

第二期作之結果如表 2 所示。稻穀容重於臺稉 2 號在氮肥處理間差異不顯著，而臺農67號、臺稉 6 號及臺中秈10號隨施氮量增加遞減。糙米容重於各參試品種對施氮量的反應，臺稉 2 號及臺中秈10號在氮肥處理間差異不顯著，臺農67號及臺稉 6 號皆以在施氮量60kg/ha時最高。臺稉 6 號及臺中秈10號在施氮量間差異不顯著，雖然臺農67號及臺稉 2 號在處理間差異顯著，但差距值不超過百分之一。白米率於參試品種在氮肥處理間差異不顯著；完整米率除臺農67號在施氮量150kg/ha較低外，其他品種在施氮量間差異均不顯著。直鏈性澱粉含量對施氮量之反應，臺農67號、臺稉 6 號及臺中秈10號在施氮量間差異不顯著，臺稉 2 號於施氮量90kg/ha以上之處理差異亦不顯著。粗蛋白質隨施氮量增加而增加，除臺稉 2 號在施氮量120kg/ha及150kg/ha差異顯著外，其他品種在上述兩處理間皆呈差異不顯著。膠體性質於所有參試品種在氮肥處理間差異不顯著。

由於第一、二期作之粗蛋白質含量及第二期作之稻穀容重、糙米率、白米率、完整米率、直鏈性澱粉含量及膠體性質等性狀的品種與施氮量間不具有交感效應，可針對氮肥或品種處理主效應進行比較，以進一步瞭解平均所有參試品種之各性狀受施氮量的影響，以及不考慮氮肥施用量下各品種之綜合表現之差異。表 3 爲不同品種或氮肥處理等級下品質性狀平均值之比較，由表顯示第一期作粗蛋白質含量於平均所有參試品種對氮肥之綜合表現，隨施氮量增加而明顯遞增，以臺中秈10號的表現明顯高於其他品種，臺農67號次之，臺稉 2 、 6 號最低。第二期作稻穀容重於平均所有參試品種隨氮肥增加明顯遞減，施氮量90kg/ha以下之處理差異不顯著，各品種之綜合表現以臺中秈10號表現最差，其他品種差異不顯著。糙米率及白米率於平均所有參試品種在施氮量間差異不顯著，各品種之綜合表現兩者皆以臺稉 2 號表現最佳，臺農67號次之，臺中秈10號表現最差；完整米率於平均所有參試品種在施氮量間差異不顯著，各品種之綜合表現以臺農67號及臺稉 2 號表現最佳，臺稉 6 號次之，臺中秈10號最差。直鏈性澱粉含量於平均所有參試品種在施氮量間差異亦不顯著，以臺稉 6 號及臺中秈10號之平均含量最高，臺農67號次之，臺稉 2 號最低。粗蛋白質含量於平均所有參試品種隨施氮量增加而增加，以臺中秈10號最高，臺農67號及臺稉 2 號次之，臺稉 6 號最低。膠體性質於平均所有參試品種在施氮量間差異不顯著，測定值以臺稉 2 、 6 號表現最高，臺農67號次之，臺中秈10號最低。

表 2. 第一、二期作各別品種之不同氮肥等級的稻米品質平均值

Table 2. Means of rice quality for rice cultivars under different nitrogen rates in the two rice crops.

Varitey	Nitrogen rates (kg/ha)	Volume wt. of paddy rice (g/l)	Volume wt. of brown rice (g/l)	Brown rice rate (%)	Milled rice rate (%)	Head rice rate (%)	Amylose content (%)	Crude protein content (%)	Gel consistency (mm)
					1st rice crop				
Tainung 67									
	60	553.1a	823.5a	82.0ab	73.0a	67.0a	18.3ab	6.4b	81.7a
	100	544.8a	821.3ab	82.2a	73.1a	66.0ab	18.6a	6.8c	80.1ab
	140	531.0b	817.6bc	81.8b	73.0a	65.3b	17.5bc	7.5b	77.9bc
	180	516.5c	815.0c	81.8b	72.4b	63.0c	17.3c	7.9a	76.4c
	L.S.D.	9.1	4.4	0.3	0.3	1.0	0.7	0.3	2.7
Taikeng 2									
	60	542.3a	819.5a	81.4a	73.1ab	68.5ab	18.1a	6.3c	79.7a
	100	535.5b	819.0a	81.6a	73.4ab	68.9a	18.3a	6.7b	82.1a
	140	530.1bc	822.0a	81.7a	73.5a	67.8ab	17.3b	7.4a	80.3a
	180	525.0c	819.0a	81.2a	72.6b	67.1b	17.5b	7.5a	78.5a
	L.S.D.	5.6	7.0	0.6	0.8	1.5	0.4	0.3	4.3
Taikeng 6									
	60	540.8a	811.5a	81.0a	71.2a	64.7ab	17.8a	6.2c	78.9ab
	100	530.8ab	809.1ab	81.2a	71.4a	65.2a	17.8a	6.8b	81.0a
	140	525.5b	808.3ab	81.1a	71.3a	63.6ab	17.5ab	7.3a	79.4ab
	180	513.3c	805.6b	80.9a	71.2a	62.6b	17.3b	7.5a	76.5b
	L.S.D.	11.6	5.0	0.5	0.8	2.1	0.4	0.3	4.1
Taichung Sen 10									
	60	533.3a	794.5a	78.1b	69.7b	63.3b	17.5a	6.7d	79.4a
	100	533.0a	793.6a	78.1b	69.8b	58.9c	17.1a	7.1c	77.5ab
	140	530.0a	796.0a	78.3ab	70.5a	66.4a	15.9b	7.6b	74.2b
	180	522.6b	796.8a	78.8a	70.6a	67.2a	16.1b	7.9a	70.5c
	L.S.D.	3.5	4.2	0.5	0.4	1.4	0.8	0.3	3.4
	Mean	531.7	810.8	80.7	71.9	65.3	17.5	7.0	78.4
					2nd rice corp				
Tainung 67									
	60	534.5a	816.5a	82.1ab	74.0a	71.4a	19.1a	7.4b	71.1a
	90	529.5ab	812.5b	82.0b	73.7a	71.0ab	19.4a	7.7b	67.5a
	120	526.8b	814.3ab	82.1ab	74.1a	71.3ab	19.4a	8.2a	68.8a
	150	524.8b	814.6ab	82.3a	74.3a	70.3b	19.6a	8.4a	68.4a
	L.S.D.	5.3	3.4	0.3	1.0	1.1	0.6	0.3	6.1
Taikeng 2									
	60	529.5a	824.3a	8.2b	75.0a	71.5a	18.7b	7.4d	73.7a
	90	528.5a	826.1a	82.7ab	75.2a	71.5a	18.9ab	7.9c	72.0a
	120	530.3a	828.0a	82.7ab	75.2a	71.4a	19.5a	8.2b	70.0a
	150	524.6a	823.3a	83.1a	75.3a	71.4a	19.2ab	8.6a	72.0a
	L.S.D.	6.7	4.9	0.4	0.6	0.5	0.8	0.3	4.5
Taikeng 6									
	60	536.1a	817.5a	81.7a	73.5a	69.8a	19.4a	7.2b	73.4a
	90	533.0a	809.5b	81.6a	73.1a	70.9a	19.6a	7.3b	71.9a
	120	532.1a	816.1a	81.8a	73.5a	70.6a	19.7a	7.8a	73.1a
	150	521.5b	812.3b	81.5a	73.2a	70.0a	19.7a	8.2a	74.3a
	L.S.D.	7.3	3.4	0.7	0.8	1.5	0.4	0.4	6.3
Taichung Sen 10									
	60	518.0a	794.6a	78.6a	70.8a	67.5a	19.7a	7.9b	63.8a
	90	512.3a	795.0a	78.7a	70.9a	68.0a	19.8a	8.2ab	63.6a
	120	512.0a	792.1a	78.6a	71.1a	68.3a	19.9a	8.6a	64.4a
	150	502.8b	791.6a	78.9a	70.7a	68.2a	19.5a	8.7a	64.6a
	L.S.D.	6.9	4.8	0.8	0.8	2.2	0.6	0.5	6.0
	Mean	511.3	811.8	81.3	73.4	70.2	19.4	8.0	69.5

Means followed by same letters are not significantly different at 0.05 level.

表 3. 第一、二期作品種或氮肥之稻米品質平均值

Table 3. Means of rice qaulity under different rice cultivars or nitrogen rates in the two rice crops.

Treatment	Volume wt. of paddy rice (g/l)	Volume wt. of brown rice (g/l)	Brown rice rate (%)	Milled rice rate (%)	Head rice rate (%)	Amylose content (%)	Crude protein content (%)	Gel consistency (mm)
				1st rice crop				
Nitrogen (kg/ha)								
60	542.4a	812.2a	80.6a	71.7ab	65.9a	17.9a	6.4d	79.9a
100	536.0b	810.7ab	80.8a	71.9ab	64.7b	17.9a	6.8c	80.2a
140	529.1c	811.0ab	80.7a	72.1a	65.8a	17.1b	7.4b	76.3b
180	519.3d	809.1b	80.7a	71.7b	64.9b	17.1b	7.7a	77.1b
L. S. D.	5.0	3.0	0.2	0.3	0.8	0.4	0.2	2.4
Variety								
Tainung 67	536.3a	819.3a	81.9a	72.9a	65.3b	17.9a	7.1b	79.0a
Taikeng 2	533.2ab	819.8a	81.5b	73.2a	68.1a	17.8ab	7.0c	80.2a
Taikeng 6	527.6c	808.6b	81.0c	71.3b	64.0c	17.6b	7.0 c	78.9a
Taichung Sen 10	529.7bc	795.2c	78.3d	70.1c	63.9c	16.6c	7.3a	75.4b
L. S. D.	3.8	2.3	0.2	0.2	0.7	0.2	0.1	1.4
				2nd rice crop				
Nitrogen(kg/ha)								
60	529.5a	813.2a	81.2a	73.3a	70.0a	19.2a	7.5d	70.5a
90	525.8ab	810.7bc	81.3a	73.2a	70.3a	19.4a	7.8c	68.7a
120	525.3b	812.6ab	81.3a	73.5a	70.4a	19.6a	8.2b	69.8a
150	518.4c	810.5c	81.4a	73.4a	70.0a	19.5a	8.5a	69.1a
L. S. D.	3.7	2.1	0.3	0.4	0.6	0.5	0.2	3.2
Variety								
Tainung 67	528.9a	814.5b	82.1b	74.0b	71.0a	19.4b	7.9b	68.9b
Taikeng 2	528.2a	825.4a	82.7a	75.2a	71.4a	19.0c	8.0b	71.9a
Taikeng 6	530.7a	813.8b	81.7c	73.3c	70.3b	19.6ab	7.6c	73.2a
Taichung Sen 10	511.2b	793.3c	78.7d	70.9d	68.0c	19.7a	8.3a	64.1c
L. S. D.	3.1	2.0	0.3	0.3	0.5	0.2	0.2	2.5

Means followed by same letters are not significantly different at 0.05 level.

三、氮肥之效應反應

進一步就各試驗品種的性狀對氮肥用量之關係求配反應模式，圖 1 爲第一期作不同参試品種之各個調查性狀對氮肥處理之反應曲線。参試稉型品種之稻穀容重（圖1-A）對施氮量呈直線關係，迴歸係數爲負值，而臺中秈10號對施氮量呈二次曲線反應，而且各反應模式的決定係數皆在或高於百分之五十左右。臺農67號及臺稉 6 號之糙米容重（圖1－B）對施氮量呈直線關係，迴歸係數爲負值，顯示施氮量越多糙米容重越輕，但決定係數偏低，而臺稉 2 號及臺中秈10號之糙米容重與施氮量不具線性關係。糙米率（圖1-C）對施氮量之反應，唯有臺中秈10號呈直線關係，隨施氮量增加遞增，其他稉型参試品種對施氮量不呈線性關係。施氮量對白米率（圖1-D）之影響，臺農67號及臺稉 2 號呈二次曲線關係，臺中秈10號呈直線關係，臺稉 6 號則不呈線性關係；各品種之完整米率（圖1-E）對施氮量的反應，参試稉稻品種雖皆呈直線關係，迴歸係數皆爲負值，但決定係數皆偏低，臺中秈10號則呈三次曲線反應；所有品種之直鏈性澱粉含量（圖1-F）與施氮量皆呈直線關係，迴歸係數皆爲負值，顯示在本試驗氮肥處理範圍內，施氮量愈高直鏈性澱粉含量愈低，唯決定係數皆偏低。所有参試品種之粗蛋白質含量（圖1-G）與施氮量呈直線關係，迴歸係數爲正值，即粗蛋白質含量隨施氮量增加遞增，只是決定係數亦偏低。各品種之膠體性質（圖1-H）受施氮量之影響，臺農67號呈直線關係，臺稉 6 號則呈二次曲線關係，臺中秈10號呈三次曲線關係，臺稉 2 號則不具有線性關係。

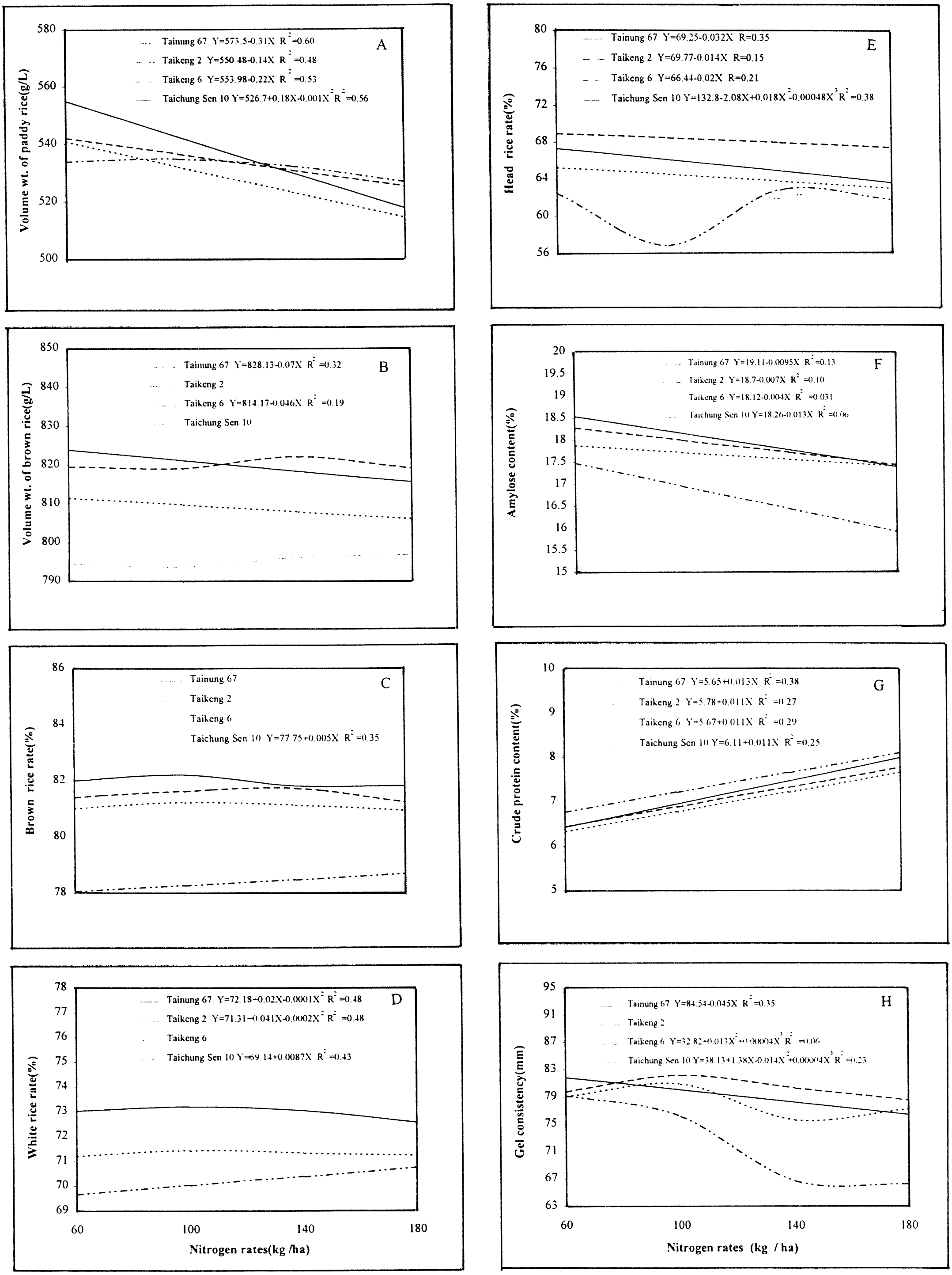

圖 1. 第一期作氮肥處理對碾米品質理化性質及稻穀與糙米容重之影響

Fig. 1. Effect of nitrogen application on milling quality, physicochemical properties and volumn weights of paddy and brown rice in the 1st rice crop.

圖 2 為第二期作不同參試品種之調查性狀對氮肥處理之反應曲線。施氮量與稻穀容重（圖2-A）之關係，除臺稉 2 號不具線性關係外，臺農67號、臺稉 6 號及臺中秈10號皆呈直線關係，回歸係數皆呈負值。施氮量對糙米容重（圖2-B）之影響，除臺稉 6 號呈三次曲線關係外，其他參試品種皆不具線性關係。施氮量對糙米率（圖2-C）之影響，臺農67號及臺稉 2 號呈直線關係，迴歸係數為正值，臺稉 6 號及臺中秈10號則無線性關係。所有參試品種之白米率（圖2-D）、完整米率（圖2-E）、直鏈性澱粉含量（圖2-F）及膠體性質（圖2-H）與施氮量皆不具有線性關係。所有品種之粗蛋白質含量（圖2-G）與施氮量呈直線關係，迴歸係數為正值，此結果與第一期作之結果相同（圖1-G）。

四、品質性狀間之相關性

雖然上述已就各品種之性狀受施氮量影響的反應曲線進行探討，然而並無法瞭解各調查之品質性狀受氮肥處理影響下，彼此互動的關聯性，尤其是稻穀容重及完整米率與各性狀之關係，基此，進一步就調查性間進行相關性分析。表 4 為參試稉型稻之碾米品質、理化性質、稻穀容重及糙米容重及碾米品質性狀（糙米率、白米率及完整米率）呈顯著正相關，與理化性質中的粗蛋白質含量呈顯著負相關。完整米率與糙米容量、白米率、糙米率、直鏈性澱粉含量及膠體性質呈顯著正相關。直鏈性澱粉含量、粗蛋白質含量及膠體性質等性狀彼此間呈顯著正相關。第二期作稻穀容重與鏈性澱粉含量呈顯著負相關，與其他性狀相關係數不顯著。完整米率與糙米率及白米率呈顯著正相關，與其他性狀之相關係數則呈不顯著，直鏈性澱粉含量與膠體性質呈顯著負相關，粗蛋白質含量與膠體性質呈顯著正相關。表 5 為第臺中秈10號之碾米品質、理化性質、稻穀容重及糙米容重的相關係數，由表顯示第一期作稻穀容量與碾米品質性狀呈顯著負相關，與粗蛋白質含量亦呈顯著負相關。完整米率與白米率、直鏈性澱粉含量及粗蛋白質含量呈顯著正相關。直鏈性澱粉含量、粗蛋白質含量及膠體性質等性狀彼此間之相關係數呈顯著正相關。參試稉稻品種之稻穀容積重越重所得之完整米率越高，臺中秈10號恰與其相反，此差異可能與粒形長短有關。第二期作稻穀容重與糙米容重、白米率、完整米率及膠體性質呈顯著正相關。完整米率與糙米容重呈顯著正相關，與白米率、粗蛋白質含量及膠體性質顯著正相關。粗蛋白質含量與膠體性質呈顯著正相關。

表 4. 參試稉型品種之碾米品質、理化性質及稻穀容重間的相關性

Table 4. Correlations among milling quality, physicochemical properties and volume weights of paddy and brown rice in japonica rice in the two rice crops.

Source			(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Volume weight	(A)	1st	1.00							
of paddy rice		2nd	1.00							
Vloume weight	(B)	1st	0.51**	1.00						
of brown rice		2nd	0.08	1.00						
Brown rice	(C)	1st	0.42**	0.51**	1.00					
rate		2nd	−0.15	0.29*	1.00					
Milled rice	(D)	1st	0.28*	0.65**	0.70**	1.00				
rate		2nd	−0.12	0.51**	0.92**	1.00				
Head rice rate	(E)	1st	0.29*	0.47**	0.34**	0.72**	1.00			
		2nd	0.11	0.23	0.45**	0.45**	1.00			
Amylose content	(F)	1st	−0.04	0.16	0.07	0.31**	0.47**	1.00		
		2nd	−0.31**	−0.23	−0.03	−0.09	−0.16	1.00		
Crude protein	(G)	1st	−0.72**	−0.15	−0.20	0.10	0.05	0.46**	1.00	
content		2nd	−0.21	0.50**	−0.17	−0.02	−0.08	−0.10	1.00	
Gel consistency	(H)	1st	−0.05	0.12	0.11	0.26*	0.41**	0.72**	0.33**	1.00
		2nd	0.21	0.48**	−0.43**	−0.26	−0.14	−0.29*	0.66**	1.00

*,** significant at 0.01 and 0.05 levels of probability, respectively.

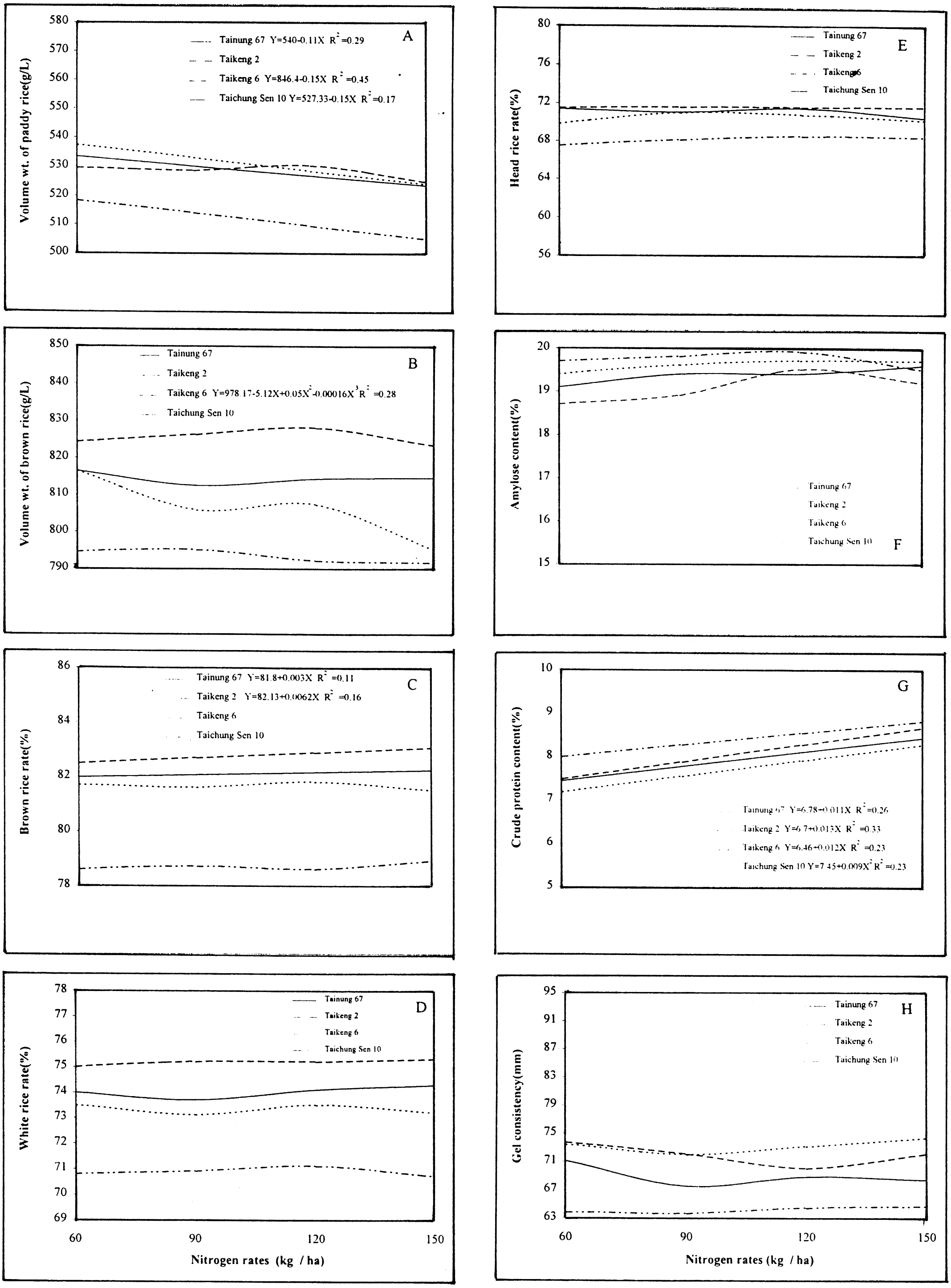

圖2. 第二期作氮肥處理對碾米品質理化性質及稻穀與糙米容重之影響

Fig. 2. Effect of nitrogen application on milling quality, physicochemical properties and volumn weights of paddy and brown rice in the 2nd rice crop.

表 5. 臺中秈10號之碾米品質、理化性質及稻穀容重間的相關性

Table 5. Correlations among milling quality, physicochemical properties and volume weights of paddy and brown rice in the taichung sen 10 in the two rice crops.

Source			(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Volume weight	(A)	1st	1.00							
of paddy rice		2nd	1.00							
Vloume weight	(B)	1st	−0.11	1.00						
of brown rice		2nd	0.66**	1.00						
Brown rice	(C)	1st	−0.46*	0.40	1.00					
rate		2nd	−0.08	−0.23	1.00					
Milled rice	(D)	1st	−0.50*	−0.20	0.38	1.00				
rate		2nd	0.64**	0.55**	0.43*	1.00				
Head rice rate	(E)	1st	−0.54*	−0.11	0.32	0.63**	1.00			
		2nd	0.63**	0.44*	0.26	0.81**	1.00			
Amylose content	(F)	1st	0.03	−0.60	−0.24	0.18	0.45*	1.00		
		2nd	0.03	−0.34	0.47*	0.02	−0.17	1.00		
Crude protein	(G)	1st	−0.54**	−0.45*	0.11	0.74**	0.62**	0.55**	1.00	
content		2nd	0.24	0.20	0.25	0.58**	0.66**	0.11	1.00	
Gel consistency	(H)	1st	0.03	−0.61**	−0.29	0.02	0.25	0.93**	0.46**	1.00
		2nd	0.73**	0.54**	−0.11	0.57**	0.70**	−0.03	0.61**	1.00

*, ** significant at 0.01 and 0.05 levels of probability, respectively.

討 論

近年來臺灣國民對食米的要求已不再只是單純的「吃得飽」，而是要「吃得好」、「吃得巧」，再加以消費習性改變，國人對稻米的需求量逐年減少，而外銷受限，導致稻米生產過剩、倉容不足等問題產生，形成本省農政上莫大困擾。爲因應稻米消費由量的時代轉變爲質的時代，政府已展開一連串生產銷售的改進工作，包括資助農業改良場所針對稻米品質進行品種選育，對適合生產優良稻米的地區進行規劃，並訂定銷售小包裝白米三級分級標準等等。經濟部中央標準局更於84年對稻穀、糙米及白米訂定新標準，並規定生產之稻米依 CNS 標準檢驗，合乎一等稻穀、一及二等糙米與一及二等白米之標準者，方有進入評定良質米的資格，這一切措施皆爲落實建立分級收購制度，任何一位生產者對此一趨勢都應有所瞭解與認知。

長期以來，農民爲提高純收益皆以栽種抗病蟲害且豐產的品種爲主，對品種品質之良窳較不重視，只一味追求稻穀產量豐收；再加以本省皆爲小農制之農戶，施肥費用佔栽種成本比例很小，農民施肥習慣不易改變，這種種因素導致現今稻田之施肥量普遍偏高，尤其是對稻穀產量最有直接貢獻的氮肥最爲嚴重。此施氮習性若不改善，可能對生產所謂的良質米會發生很大阻礙。氮肥對稻米品質之影響報告及論述很多，本研究擬就穀粒特性及碾米品質作論述，以再次闡明氮肥對稻穀生產品質之影響，希望能提供稻作實際生產者之參考。

稻穀容積重最主要取決於品種之遺傳特性，如芒的有無、粒型、穀粒光滑等，此外受充實度之影響甚巨，而稻穀之充實與營養供給有很大關聯。根據經濟部中央標準局新訂定之稻穀最低容積重標準稉稻一等爲560g/l，秈稻爲520g/l（詳見CNS2423號），而本研究第一期作稻穀容重之品種與氮肥間具有顯著交感效應，第二期作則不顯著（表1），第一期作各品種之稻穀容重隨施氮量增加而減少（表2），其中稉型參試品種當施氮量由100kg/ha增加至140kg/ha時，稻穀容重減少最顯著，就中以臺農67號於施氮量60kg/ha時之容積最重，然而亦無法達到一等稻穀之標準；臺中秈10號則於施氮量

140kg/ha與180kg/ha間稻穀容重差異最大，而即使於施氮量180kg/ha時之容重亦符合秈稻一等標準。第二期作之稻穀容重受施氮量之影響雖然不若第一期作明顯，然亦隨施氮量增加而減少，當施氮量由120kg/ha增加至150kg/ha時減少最顯著（表３），而且所有參試品種之所有處理的容重皆未達一等稻穀標準。顯見期作對稻穀之容積重影響甚劇，而中央標準局在訂定稻穀最低容積重時，似乎亦應將期作因素列入考慮方才合理。再則本試驗所使用之稉型品種的稻穀容積重皆無法達到一等稻穀標準，顯示中央標準局所訂定的稉稻稻穀容重可能太高，而未來在進行水稻品種改良時，對於稻穀容重該性狀亦應嚴加注意。

衆所周知，從事稻米加工之販賣者，其希望購得之稻穀是能碾製較多量糙米(尤其是高完整米率)之稻穀。新訂定之良質米的糙米標準必須在二等以上，一等糙米之完整米率需在75%以上，二等糙米之完整米率需在65%以上，秈稻之一等糙米需在70%以上，二等糙米需在60%以上（詳見 CNS2424號）。本試驗之完整米率其品種與氮肥間的交感效應，第一期作顯著，第二期作則不顯著（表１）。第一期作各別參試稉稻之完整米率與施氮量呈直線關係（圖１），臺農67號之完整米率於施氮量180 kg/ha時無法達到二等糙米的標準（表２），臺稉６號在施氮量超過100kg/ha時亦無法達到二等糙米標準，而臺稉２號之完整米率不受施氮量的影響，皆界於一等與二等糙米標準之間；臺中秈10號之完整米率對施氮量之反應與參試稉稻不同，施氮量於140kg/ha以上時完整米率皆達一等糙米的水準。第二期作各品種之完整米率對氮肥之反應差異不顯著，與施氮量不具直線關係，然而皆明顯較第一期作爲高，所有參試稉稻品種的各處理之完整米率均達到二等糙米標準，臺中秈10號之完整米率與施氮量的關係不顯著，但均達一等糙米的標準。顯示本試驗中氮肥對完整米率隨期作及品種之不同而有差異。整體而言，氮肥對參試稉稻之完整米率於第一期作有負面效果，第二期作有正面效應，對臺中秈10號之完整米率則無影響。宋[1]曾指出施氮量對完整米率有正面效果，原因乃施氮量延遲了水稻的成熟期，導致稻穀收穫水分增加所造成。本試驗之第二期作雖與宋氏的結果相同，但第一期作則正好相反。雖然本試驗未對收穫之試驗小區穀粒進行含水量測量，收穫時各小區稻穀成熟程度確有差異，稻穀之收穫水分互有不同，烘乾的過程相同，烘乾後之稻穀含水量差異亦在１%以內，唯有烘乾的時間長短有差異，而第一期作完整米率與稻穀容重呈顯著正相關，稻穀容重與穀粒充實程度有關，因此施氮量對完整米率之影響，第一期作可能因氮肥增加導致收穫時穀粒充實程度不佳有關。成熟期之日夜溫差對水稻碾米品質有很大影響[11]，郭等[8]曾依其試驗結果展延推定指出較低溫下（有限制）成熟之穀粒由於充實速率降低及充實期間延長致米粒澱粉顆粒之累積較緻密，使之更具碾白抵抗力而不易碎裂，提高完整米率。臺灣第一期作穀粒之充實期正值高溫，日夜溫差小，第二期作穀粒充實期時溫度較低，日夜溫差大，而本試驗之結果亦顯示第二期作之完整米率高於第一期作，與郭等推論相符。

蛋白質雖是決定稻米營養價值的最主要因素，尤以氨基酸中之離氨酸的含量最重要，宋及劉[3]指出土壤質地及施肥方法之不同，蛋白質含量差異可達６%。郭[6]亦歸納指出米粒蛋白質含量隨氮肥之施用量、施用方法、施用時期的不同而有顯著差異。近年來由於高蛋白質的米飯口感差，且米飯蛋白質並非人類攝取蛋白質之主要來源，近年來國內秈稉稻育種都有走向低蛋白質含量選拔的趨勢[3]，因此施氮量對米粒蛋白質含量之影響更顯重要。研究顯示兩期之米粒粗蛋白質在品種與施氮量交感效應均不顯著，品種間及施氮量間差異皆極顯著，同時粗蛋白質與氮肥用量呈直線關係，即含量隨施氮量增加而增加，在第一期作當施氮量由100kg/ha增加至140kg/ha，第二期作施氮量由90kg/ha增加至120kg/ha時粗蛋白質大幅增加。相同品種在第二期作之粗蛋白質高於第一期作，此結果與趙[12]指出米粒之蛋白質含量因栽培期作不同而異的結果相同。

含低量直鏈性澱粉之米粒，煮成飯時較粘而濕潤，較受本省消費者喜愛，因此，時下育成之新品種的直鏈性澱粉含量皆低。Juliano[19]指出同一品種因環境不同可達６%之差異。郭[8]亦指出品種間及栽培地點間米粒直鏈性澱粉含量差異顯著。本研究之同一品種的直鏈性澱粉含量在第二期作量高於

第一期作，第一期作直鏈性澱粉含量與施氮量呈直線關係，隨施氮量增加而減少，尤其於施氮量由100kg/ha增加至140kg N /ha時，所有品種之降低幅度最劇，施氮量140kg/ha及180kg/ha則差異不顯著，第二期作施氮量間差異不顯著。顯示於第一期作適當施用氮肥對降低米粒中之直鏈性澱粉含量有幫助，而第二期作栽種時期之氣溫及日照對米粒中直鏈性澱粉含量之影響遠大於氮肥作用效果，以致氮肥量之多寡對其影響表現不顯著。

『稻米生產企業化；稻農生活現代化；稻田生態自然化』是未來稻作發展方向，亦是我國進入關貿總協（GATT）後因應對稻作衝擊之最高指導原則，而持續提昇本省稻米品質、降低生產成本及避免過度污染環境是一具體的步驟。適度的減少使用氮肥即可降低生產成本，亦可減少對農地生態的破壞，雖然推廣的水稻品種皆訂定有氮肥施用推薦標準量，例如第一期作在中、南、東部爲120～140 kg N/ha，二期作約100～120kg N/ha，北部一期作爲110～130kg N/ha，第二期作80～100kg N/ha [16]，然一般農民爲追求高產均將施氮量提高許多。從本試驗結果顯示臺灣的中部地區第一期作氮肥施用量以不超過140kg/ha爲宜，第二期作則可降低至90kg/ha，收穫之稻穀產量及品質均有較佳表現，提高施用量對增加稻穀生產量不但幫助有限，而且會導致稻穀及稻米品質下降，得不償失。

誌　　謝

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The Relationship between Grain Productivity and Nitrogen-fertilizer Rate of Currently Cultivated Rice Cultivars

II. The Effects of Different Nitrogen Rates on Volume Weight and Quality Traits in Rice[1]

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Summary

In order to elucidate the relationship between nitrogen-fertilizer rate and grain productivity for currently cultivated rice cultivars of Taiwan, the field experiment was conducted at the experimental farm of Taiwan Agricultural Research Institute under four nitrogen rates (60, 100, 140, 180kg N/ha for the 1st rice crop ; 60, 90, 120, 150kg N/ha for the 2nd rice crop) in 1993 and 1994 using four rice cultivars, Tainung 67, Taikeng Nos. 2 and 6, and Taichung Sen 10 (TCS 10) as the experimental materials. This article presented is emphasizing on the performances of volume weights of paddy and brown rice, milling quality and physicochemical properties. In the 1st rice crop linear responses, increasing in amount of nitrogen fertilizer show decreasing in volume weight of paddy rice and head rice rate, were observed for all 3 sinica cultivars. On the other hand, quadratic and cubic responses to nitrogen were respectively indicated for volume weight and head rice rate of TCS 10, the indica cultivar. As to physicochemical properties evaluated, linear trends of effects of nitrogen rate were shown for those properties with the exception of gel consistency. However, trends were different depending on traits, that is, lower amylose content and higher protein content were observed as nitrogen rate increased. In the 2nd rice crop, it is indicated that as nitrogen rate increased, heavier volume weight of paddy rice was found for all rice cultivars except for Taikeng No. 2. Data indicated that the trends of both head rice tate and amylose content of milled rice due to different nitrogen fertilizer rates were not significant. In addition, higher protein content was indicated as nitrogen increased. From the results obtained, it might be concluded that decreasing in amount of nitrogen fertilizer could resulted in increasing in volume weight of paddy rice, but decreasing in protein content of milled rice, however, the effect of mitrogen rates to the performances of head rice rate and amylose content appear to be different, i. e. depending on crop seasons. Considering grain yield potential and quality, it is recommended that the optimal nitrogen-fertilizer rate is 140kg/ha for the 1st rice crop and 90kg/ha for the 2nd rice crop, respectively, Higher nitrogen rate should result in decreasing of grain quality of rice.

Key words : Rice, Nitrogen, Volume weight, Rice grain quality.

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Griffing and Hayman Diallel Analyses of Variance for Eating and Processing Quality Parameters of Milled Rice[1]

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Abstract: Amylose content and amylographic viscosity measurements, both chemical and physical properties of milled rice, are important eating and processing quality parameters and are characteristics of a endosperm. A six-parent diallel cross was made and, thus, a genetic study on such endosperm characteristics was conducted. Since amylose contern and amylographic viscosity measurements are difficult to be determined on a single grain basis, samples of bulking heterozygous F_2 grains from combining homogeneous heterozygous F_1 plants were used as measurement units. Results of Griffing's and Hayman's diallel analyses of variance for the parameters, amylose content and amylographic peak, hot-paste, cool-paste, breakdown, setback and consistency viscosities, are respectively presented. It was evident that gene action in the parents studied was mainly additive for all evaluated endosperm characteristics, although dominance effects were also involved. The fact that reciprocal differences in both Griffing's and Hayman's diallel analyses were not significant indicated that Hayman's assumption (2) no differences between reciprocal crosses was met in this study. Date indicated that significant dominance gene effects wer due to a directional dominance effect, an asymmetry of the gene distribution, and a residual dominance effect for all studied quality parameters except for hot-paste viscosity, in which the effect of an asymmetry of the gene distribution was not significant.

Key words: Amylose content, Amylographic viscosity measurements, Diallel analysis, Endosperm characteristics, Milled rice.

INTRODUCTION

Amylose content and amylographic viscosity measurements of milled rice, considered mainly as eating and processing quality parameters, are characteristics of the endosperm, which is a triploid tissue resulting from the fusion of one sperm nucleus with the two polar nuclei of the egg. Thus, reciprocal differences (including maternal and/or dosage effects, xenia) are supposedly existed and the grains on a plant of segregating generations represent the next generation of the plant. Furthermore, for endosperm characteristics, an individual is a

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seed, not a plant. That is, these characteristics should be measured on a single grain basis. Unfortunately, there are many endosperm characteristics which are difficult to measure on the basis of single seed and a satisfactory genetic model for such endosperm characteristics has not yet been developed. Up to present, a method for determining amylose content on the basis of single grain has already been developed and few papers has paid attention to solve the lack of proper genetic models for those endosperm characteristics[23,24,25,28]. However, determination of amylographic viscosity measurements has not been developed yet. All seeds on a plant have to be taken as a measurement unit. On the other hand, a diallel cross which consists of mating several parental entries in all possible combinations, allows a genetic analysis to be carried out after one generation and may provide a large simple size of measurement unit for endosperm characteristic by combining all F_2 grains from some homogeneous heterozygous F_1 plants. Thus, using the first filial generation with the parents and requiring fewer individuals, genetic and beeding information about endosperm characterisitics can be obtained[16].

Up to now, several methods have been proposed for the analysis of data from a diallel cross [6,7,9,10,12]. Liu[19], Mather and Poysa [21], and Sokol and Baker[26] have demonstrated basic similarity of these methods. The approaches of Griffing[6] (Method I, Model I) and Hayman [9,10] are statistically similar, In their analyses of variance, the Griffing's general combining ability (GCA) component is mathematically identical to the Hayman's additive component(a). Griffing employs one specific combining ability (SCA) and one reciprocal effect component, while Hayman subdivides these into three dominance components (b_1, b_2, and b_3), and two reciprocal effect components (c and d), respectively. They differ, however, in the genetic assumptions and interpretations which are associated with them. The Griffing's analysis is a strictly statistical treatment of main effects (GCA) and interactions (SCA), whereas, the Hayman analysis incorporates genetic assumptions. In general, the Hayman's method appears to extract mor genetic information than the Griffing's method does from the same data set. The Griffing's method involves only analysis of variance and estimation of GCA and SCA effects. The Hayman's method, on the other hand, may include statistical and graphical analyses of array variances and covariances, and the estimation of a number of genetic parameters.

In this paper, data about amylose content and amylographic viscosity measurements, based upon determination of combining F_2 milled rice grains, were analyzed by both the Griffing and the Hayman diallel analyses of variance and the genetic control about those quality parameters of rice are discussed.

MATERIALS AND METHODS

All possible cross-combinations, including the reciprocals, were made among six rice entries, "Rexmont", "Guichow", "Lemont", "Cl 9902", "Toro ll", and "Taichung Sen No. 10" (TCS 10), representing an array of different levels of amylose content and amylographic measurements as shown in Fig. 1 and Table 1. The six parents and one set of F_1 hybrids, 30 combinations, were transplanted and cultivated in a flooded paddy field at the Texas A&M University Agricultural Research and Extension Center near Beaumont, Texas, in a randomized complete block design with three replications. Each block consisted of 36 four-row plots. Each plot included 40 plants spaced at 30×30 cm. Twenty plants from the two central rows of each plot were harvested and analyzed.

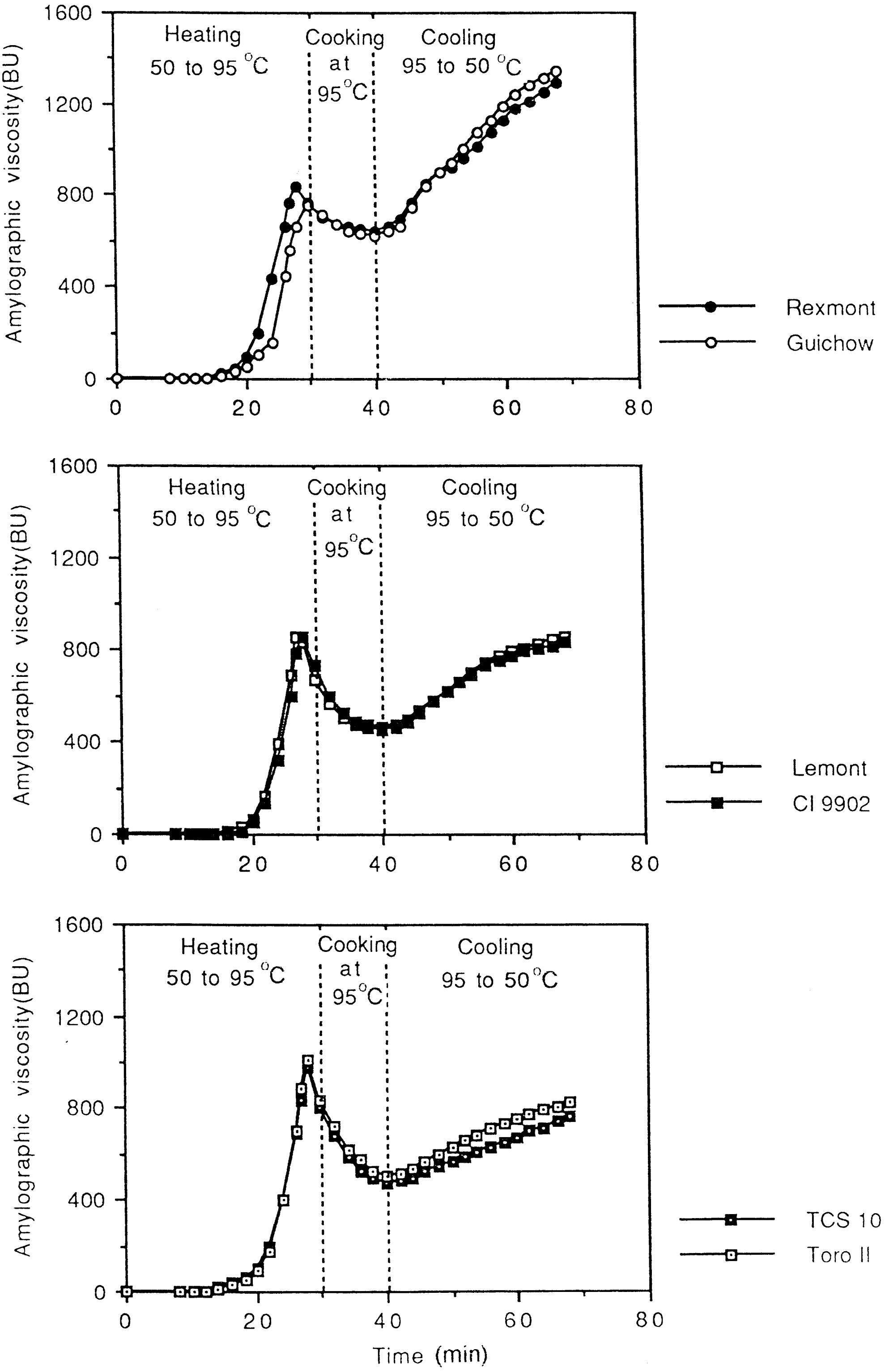

Fig. 1. Amylographic profiles of the six parents used in the diallel cross.

Table 1. Means values of amylose content and amylographic viscosity measurements of the six rice parental entries.

Parent	Amylose content (%)	Amylographic viscosity(BU)^z					
		Peak	Hot-paste	Cool-paste	Breakdown	Setback	Consistency
Rexmont(P1)	26.3	833	640	1,290	193	457	650
Guichow(P2)	27.4	747	620	1,340	127	593	720
Lemont(P3)	22.3	843	463	857	380	13	393
Cl 9902(P4)	22.6	853	470	843	383	− 10	373
TCS 10(P5)	14.5	997	490	757	507	−240	267
Toro 1l(P6)	15.2	1,010	510	803	500	−207	293

^{z} Brabender Unit.

Amylose content of milled rice was analyzed by a totally automated system of amylose analysis in white milled rice innovated by Webb[28]. Amylographic pasting characteristics were determined by the method developed by Halick and Kelly[8] and further modified for use at the Regional Rice Quality Laboratory, USDA, Beaumont, Texas, using a Brabender Visco/Amylograph with 700g.cm sensitivity cartridge and 75 rpm speed (C. W. Brabender lnstruments lnc., S. Hackensack, NJ). The detailed procedure had been outlined in previous paper[17].

The Griffing (method I, Model I) and Hayman diallel analyses of variance were performed based upon the original models and assumptions[6,7,9,10]. In each analysis of variance, the "a" item is an estimate of genetic variation among parents; the "b" item is an estimate of dominance variance sat some of the loci; the b_1 item is an estimate of mean dominance deviation of the F_1's from their mid-parent values; the b_2 item is an estimate of the mean dominance deviation of the F_1 from their mid-parental values within each array differing over arrays; the $b_3$item is an estimate of residual dominance effect; the "c" item detects the average maternal effects of each parental line; and the "d" item detects the reciprocal difference not ascribable to "c".

RESULTS

Traditional analyses of variance for characteristics studied had revealed highly significant differences among treatments (parents and hybrids)(Table 2), indicating the presence of genotypic variability in these populations used. Further detailed analyses of variance of the diallel on quality parameters were, therefore, performed and presented as the following.

Table 2. Analysis of variance for amylose content and amylographic viscosity measurements of rice.

SOV	DF	Mean square						
		Amylose	Peak	Hot-past	Cool-paste	Breakdown	Setback	Consistency
Block	2	0.8	485.8	398.5	156.8	164.2	260.0	65.1
Treatment	35	13.7**	7,440.7**	2,770.7**	29,283.0**	13,219.4**	54,799.4**	15,347.8**
Error	70	0.26	191.5	90.9	293.6	139.4	215.1	98.1

** Significant at the 0.01 probability level.

Percent Amylose Content

The analyses of variance of the diallel table for amylose content followed by both Griffing's and Hayman's methods were presented in Table 3. The results of the significance tests for both Griffing's and Hayman's methods, as shown in Table 3, were the same. This provided a practical numerical instance to certify that both Griffing's and Hayman's analyses are statistically similar.

Table 3. Griffing and Hayman analyses of variance of amylose content in the six-parent diallel crosses of rice.

Griffing			Hayman		
SOV	DF	Mean square	SOV	DF	Mean square
GCA	5	78.87**	a	5	78.87**
SCA	15	5.43**	b	15	5.43**
			b_1	1	24.67**
			b_2	5	1.06**
			b_3	9	5.72**
Reciprocal	15	0.28	c	5	0.12
			d	10	0.36
Error	70	0.26	Error	70	0.26

** significant at the 0.01 probability level.

Heghly significant differences from the zero were observed for both GCA and SCA in Griffing's method and both items "a" and "b" in Hayman's method, respectively. The reciprocal component in Griffing's method and both items "c" and "d" in Hayman's method were not significantly different from zero. Furthermore, the mean squares for both GCA and "a" were significantly larger than those for both SCA and "b" for amylose content. According to Mather and Jinks[20], the "a" item primarily tests the significance of the additive effects of the gene, and the "b" item the dominance effects. Yates[35], on the other hand, described that such a GCA may be sometimes called "additive genetic component" or"main effect", while a SCA may be referred to as "non-additive genetic component" or "dominance component" or "interaction effect". Therefore, data shown in Table 3 indicated that the inheritance of amylose content was controlled largely by additive gene effects, although dominance gene effects were also involved. No reciprocal effect influencing amylose content was indicated.

The "b_1" item tests the mean deviation of the F_1s from their mid-parental values. it is significant only if the dominance deviations of the genes in the various entries used are predominantly in one direction. That it, there is a directional dominance effect. The "b_2" item tests whether the mean dominance deviation of the F_1s from their mid-parental values within each array differs over arrays. It will do so if some parents contain considerably more dominant alleles than others. That is, a significant "b_2" implies asymmetry of the gene distribution in the parents at the loci exhibiting dominance. The "b_3" item tests that part of

the dominance that is unique to each F_1[20]. Thus, the information from Table 3 indicated that the significant dominance effects (b) were due to a directional dominance erffect (b_1), an asymmetry of the gene distribution (b_2), and a residual dominance effect (b_3) coming from additive× additive, additive×dominance, and additive×dominance interaction effects that are not attributed to b_1 and b_2.

From the results reported here, it can be concluded that : (1)gene action in these genotypes used was mainly additive for milled rice amylose content, although dominance effects were also involved; (2) the significant dominance gene effects were due to a directional dominance effect, an asymmetry of the gene distribution, and a residual dominance effect; (3) reciprocal differences due to cytoplasmic and/or dosage, xenia effects, upon amylose content were not found;

Amylographic Peak Viscosity

There are three basic amylographic viscosity measurements: amylographic peak viscosi -ty, hot-paste viscosity, and cool-paste viscosity. From which, amylographic breakdown viscosity, setback viscosity, and consistency viscosity can be calculated. Amylographic peak viscosity is the viscosity when a aqueous suspension of starch of a given concentration is heated. Usually, peak viscosity occurs before or after the temperature of the suspension has reached to 92-95 °C. Amylographic peak viscosity is a measurement of the ability of the known starch granules to swell markedly before rupturing. Typical U. S. long-grain rice cultivars usually showed an intermediate peak viscosity[29,31,32,33]. Scientists in Japan and in Taiwan, ROC. found that sticky cooked rice has higher amylographic peak viscosity[18,27]. Thus, amylographic peak viscosity is an important index for evaluating rice grain quality.

The analyses of variance of the diallel table for both Griffing's and Hayman's methods for amylographic hot-paste viscosity were presented in Tables 4. Highly significant differences were observed for both additive gene effects (GCA and "a") and dominance gene effects (SCA and "b"), and no significant differences were found for reciprocal (maternal) component. Since the mean square ratio of additive gene effect mean squares to dominance gene effect mean squares was 6:1, it can be concluded that the inheritance of amylographic peak viscosity was controlled by both additive and dominance genes, with the additive gene effects being larger than dominance gene effects. The significant dominance effects were due to a directional dominance effect (b_1), and imbalance of gene distribution (b_2), and a residual dominance effect (b_3) resulted from additive × additive, additive × dominance, and dominance × dominance interaction effects.

From the information shown in Tables 4, it might indicate that: (1)gene action in these crosses was largely additive for amylographic peak viscosity although dominance gene effects were also involved; (2) the significant dominance gene effects were due to a directional dominance effect, an asymmetry of the gene distribution, and a residual dominance effect; (3) reciprocal differences were not detected in this characteristic;

Table 4. Griffing and Hayman analyses of variance of amylgraphic peak viscosity in the six-parent diallel crosses of rice.

Griffing			Hayman		
SOV	DF	Mean square	SOV	DF	Mean square
GCA	5	34,234.32**	a	5	34,234.32**
SCA	15	5,725.39**	b	15	5,725.39**
			b_1	1	8,634.32**
			b_2	5	5,985.86**
			b_3	9	5,257.47**
Reciprocal	15	224.81	c	5	87.41
			d	10	293.52
Error	70	191.53	Error	70	191.53

** significant at the 0.01 probability level.

Amylographic Hot-paste Viscosity

Amylographic hot-paste viscosity is measured as the paste is cooking at a specified high temperature (usually 92-95 °C) for 10 minutes. The overall relationship between amylographic hot-paste viscosity and grain quality is not clear, although Lii et al.[18] reported that amylographic hot-paste viscosity significantly positively correlated with eating quality.

Tests for significance on both Griffing's and Hayman's diallel analyses for amylographic hot-paste viscosity, presented in Table 5, were the same. Highly significantly differences from the zero were found for both additive gene effects (GCA and "a") and dominance gene effects (SCA and "b"). However, the mean squares for GCA and "a" were very much larger than those for SCA and "b" and the mean square ratio of additive gene effects to dominance gene effects was 45:1. These data suggested the although both additive gene effects and dominance gene effects influenced the phenotypic mean for amylographic hot-paste viscosity in the parent entries used, the inheritance of this characteristic was mainly controlled by additive gene effects. No significant differences were observied for reciprocal components, indicating that maternal effects upon amylographic hot-paste viscosity can be ignored in these genotypes used. The data from the analysis according to Hayman's method further indicated that the significant dominance effects (b) for this characteristic were due to a directional dominance effect (b_1), and dominance that is unique to each F_1(b_3).

From these results, one could conclude that: (1) gene action in these crosses was principally additive for amylographic hot-paste viscosity, although there were some dominance gene effects; (2) the significant dominance gene effects were due to a directional dominance effect and a residual dominance effect only; (3) reciprocal differences were insignificant.

Table 5. Griffing and Hayman analyses of variance of amylgraphic hot-paste viscosity in the six-parent diallel crosses of rice.

Griffing			Hayman		
SOV	DF	Mean square	SOV	DF	Mean square
GCA	5	17,905.80**	a	5	17,905.80**
SCA	15	395.95**	b	15	395.95**
			b_1	1	437.10**
			b_2	5	168.09**
			b_3	9	555.00**
Reciprocal	15	100.37	c	5	140.00
			d	10	80.56
Error	70	90.84	Error	70	90.84

** significant at the 0.01 probability level.

Amylographic Cool-paste Viscosity

Amylographic cool-paste viscosity is measured as the temperature of the paste is cooled down at a certain rate (usually 1.5 °Cmin.) to 50 °C after a holding period (usually 10 minutes) at a spectified high temperature (usually 92-95 °C). Typical U. S. medium-and short-grain cultivars show a comparatively low cool-paste viscosity[29,31,32,33]. In addition, a higher amylographic cool-paste viscosity combined with lower amylographic breakdown viscosity has been correlated with superior parboil-canning characteristics and quick-cooking properties [34].

Griffing's and Hayman's diallel analyses of variance for amylographic cool-paste viscosity (Table 6), indicated that the results of the significance test for both methods were the same. Highly significant differences were observed for both additive gene effects (GCA and "a") and dominance gene effects (SCA and "b"). Besides, the mean squares for GCA and "a" were much larger than those for SCA and "b" and the mean square ratio of additive gene effevts to dominance gene effects was 58:1, indicating that the inheritance of amylographic cool-paste viscosity was mainly controlled by additive gene effects even though dominance gene effects are also involved. No significant differences were found for reciprocal (maternal) components. Analysis of Hayman's method further indicated that the significant dominance effects were due to an asymmetry of the gene distribution (b_2), and a residual dominance effect (b_3). A non-significant value of b_1 shows that dominance gene effects for the characteristics are ambidirectional dominance[20]. That is, the increasing (or decreasing) genes are dominant in some parents, but sometimes are recessive in some of the other parents.

From these results, it could be concluded that: (1) gene action in these crosses is mainly additive for amylographic cool-paste viscosity, although dominance gene effects are also involved; (2) reciprocal effects might not be present; (3) the significant dominance gene effects are due to an asymmetry of the gene distribution, and a residual dominance effect;

Table 6. Griffing and Hayman analyses of variance of amylgraphic cool-paste viscosity in the six-parent diallel crosses of rice.

Griffing			Hayman		
SOV	DF	Mean square	SOV	DF	Mean square
GCA	5	193,822.10**	a	5	193,822.10**
SCA	15	3,332.67**	b	15	3,332.67**
			b_1	1	723.21**
			b_2	5	1,086.05**
			b_3	9	3,537.41**
Reciprocal	15	387.04	c	5	603.70
			d	10	383.70
Error	70	293.62	Error	70	293.62

** significant at the 0.01 probability level.

Amylographic Breakdown Viscosity

There are three derivative amylographic viscosity measurements: amylograhic breakdown viscosity, setback viscosity, and consistency viscosity. Amylographic breakdown viscosity is calculated from amylographic decrease in viscosity during cooking at 92-95°C.

Traditional U. S. long-, medium-, and short-grain rice cultivars show relatively high amylographic breakdown viscosity. In contrast, superior cooking and processing U. S. long -grain cultivars are characterized by an amylose content 2-4% higher than those of typical U. S. long-grain cultivars and a relatively low amylographic breakdown viscosity[2,3,30,32,34]. Japanese rice scientists suggested that amylographic breakdown viscosity could be selected as an index feactor for palatability evaluation[27]. Published results from Taiwan, ROC. suggested a highly significant correlation between amylographic breakdown viscosity and eating quality[18]. Amylographic breakdown viscosity, therefore, could be considered as the most important index for evaluating grain quality among all of the six amylographic viscosity measurements.

The analyses of variance of the diallel tables for both Griffing's and Hayman's methods for amylographic breakdown viscosity were enumerated together in Table 7. The results of tests for significance for both methods of analyses were the same. Highly significant differences for both additive gene effects (GCA and "a") and dominance gene effects (SCA and "b") were observed. The mean square ratio of additive gene effects to dominance gene effects was 17: 1, suggesting that the inheritance of amylographic breakdown viscosity was controlled mainly by additive, although dominance gene effects were also involved. No significant differences were found for reciprocal components, indicating that reciprocal effects upon amylographic breakdown viscosity might not have existed among the genotypes used. In addition, the adta from the analysis of Hayman's method further indicated that the significant dominance gene effects were due to a directional dominance effect (b_1), an asymmetry of the gene distribution (b_2), and a residual dominance effect (b_3), which are part of the dominance deviation that is unique to each F_1 not attributable to

b_1 and b_2[20].

The results submitted here might suggest that: (1) gene action for amylographic breakdown viscosity in these crosses was mainly additive, although dominance gene effects were also presented; (2) reciprocal effects were not found; (3) the significant dominance gene effects were due to a directional dominance effect, an asymmetry of the gene distribution, and a residual dominance effect.

Table 7. Griffing and Hayman analyses of variance of amylographic breakdown viscosity in the six-parent diallel crosses of rice.

Griffing			Hayman		
SOV	DF	Mean square	SOV	DF	Mean square
GCA	5	78,325.06**	a	5	78,325.06**
SCA	15	4,616.81**	b	15	4,616.81**
			b_1	1	10,631.17**
			b_2	5	4,773.09**
			b_3	9	3,861.73**
Reciprocal	15	120.00	c	5	34.81
			d	10	162.59
Error	70	139.43	Error	70	139.43

** significant at the 0.01 probability level.

Amylographic Setback Viscosity

Amylographic setback viscosity is a derivative amylographic viscosity measurement calculated from amylographic cool-paste viscosity minus amylographic peak viscosity. Traditional southern U. S. long-grain cultivare show a slightly positive amylographic estback viscosity. Superior cooking and processing U. S. long-grain cultivars, on the other hand, show a higher amylographic setback viscosity[2,3,30,32,34]. Thus, amylographic setback viscosity is an important inde for evaluating grain quality although more attention has traditionally been paid to amylose content and amylographic breakdown viscosity.

The results of the tests for significance for both Griffing's and Hayman's for amylographic setback viscosity were the same (Table 8). Highly significant differences for both additive gene effects (GCA and "a") and dominance gene effects (SCA and "b") were observed. It was clear that the mean squares for both GCA and "a" were significantly larger that those for both SCA and "b" and the mean square ratio of additive gene effects to dominance gene effects was 32:1. These data indicated that though the inheritance of amylographic setback viscosity was controlled mainly by additive gene effects, dominance gene effects were still involved. No significant differences in reciprocal components were detected, suggesting that reciprocal effects upon amylographic setback viscosity did not exist among these entries used. data from Hayman's diallel analysis also implied that the significant dominance gene effects were due to a directional dominance effect (b_1), an asymmetry of the gene distribution (b_2), and a residual dominance (b_3).

From the results described here, it might indicate that: (1) gene action in these crosses was mainly additive for amylographic setback viscosity, although dominance gene effects were also involved; (2) the significant dominance gene effects were due to a directional dominance effect, an asymmetry dominance of the gene distribution, and a residual dominance effect; (3) reciprocal effects were not found.

Table 8. Griffing and Hayman analyses of variance of amylographic setback viscosity in the six-parent diallel crosses of rice.

Griffing			Hayman		
SOV	DF	Mean square	SOV	DF	Mean square
GCA	5	350,065.93**	a	5	350,065.93**
SCA	15	10,863.95**	b	15	10,863.95**
			b_1	1	42,320.00**
			b_2	5	7,464.07**
			b_3	9	9,257.65**
Reciprocal	15	312.59	c	5	186.67
			d	10	375.56
Error	70	215.05	Error	70	215.05

** significant at the 0.01 probability level.

Amylographic Consistency Viscosity

Amylographic consistency viscosity is one of the derivative viscosity measurements calculated by subtracting amylographic hot-paste viscosity from amylographic cool-paste viscosity. Up to now, less attention has been paid to this characteristic.

The results of the tests for significance for both Griffing's and Hayman's diallel analyses for amylographic consistency viscosity, enumerated in Table 9. were principally the same. Highly significant differences were found for additive gene effects (GCA and "a") and dominance gene effects (SCA and "b"). Furthermore, the mean squares for both GCA and "a" were much larger that those for both SCA and "b". The mean square ratio of additive gene effects to dominance gene effects was 46:1, implying that the inheritnce if amylographic consistency viscosity was controlled largely by additive gene effects, plus some dominance gene effects. In addition, the information form the analysis according to Hayman's method indicated that the significant dominance gene effects were due to a directional dominance effect (b_1), an asymmetry of the gene distribution (b_2), and a residual dominance (b_3). No significant differences were observed for reciprocal components, suggesting that resiprocal effects upon amylographic consistency viscosity might be ignored.

From the results presented here, a sub-conclusion could be offered that: (1) gene action in these crosses was mainly additive for amylographic consistency viscosity, although dominance gene effects were also present; (2) the significant dominance gene effects were due to a directional dominance effect, an asymmetry of the gene distribution, and a residual dominance effect; (3) reciprocal differences were not detected.

Table 9. Griffing and Hayman analyses of variance of amylographic consistency viscosity in the six-parent diallel crosses of rice.

Griffing			Hayman		
SOV	DF	Mean square	SOV	DF	Mean square
GCA	5	100,342.84**	a	5	100,342.84**
SCA	15	2,191.38**	b	15	2,191.38**
			b_1	1	10,528.95**
			b_2	5	721.23**
			b_3	9	2,081.73**
Reciprocal	15	172.59	c	5	137.04
			d	10	190.37
Error	70	98.14	Error	70	98.14

** significant at the 0.01 probability level.

DISCUSSION

Although a diallel cross experiment provides a powerful method of investigating the genetic properties of a group of homozygous genotypes, the analysis of a diallel cross has suffered from several theoretical defects. That is, the genetic interpretation of the data from diallel experiments is valid only if certain assumption about the parental materials are true [9,10]. The genetic assumptions, postulated by Hayman[9,10] are: (1) diploid segregation; (2) no differences between reciprocal crosses; (3) independent action of non-allelic genes; (4) no multiple allelism; (5) homozygous parents; and (6) independent distribution of genes in the parents. Of these assumptions, some can be accepted more easily than others. From a genetic point of view, two assumptions, independent distribution of genes in the parents and independent action non-allelic genes, are biologically unrealistic in attempts to interpret the results of diallel analyses. The assumption concerning independent distribution of genes in the parents is most unrealistic to proper interpretation and seems to be least acceptable in actual practice. The assumption dealing with independent action of non-allelic genes, i. e., no epistasis, may frequently be unjustifiable[1,5,26].

The assumption of independent distribution of genes in the parents implies that the presence or absence of an allele at a particular locus is statistically independent of the presence or absence of an allele at any other locus. Thus, it seems that assuming genes are independently distributed in the parents of a dialle cross is not realistic. Failure of this assumption may result from, linkage of genes in the population from which the parents were chosen, or from the effects of sample size when sampling the parents[1]. From a review of the literature, Baker[1] pointed out that there is general agreement that failure of this assumption will often result in overestimation of the average level of dominance. However, there are conflicting reports as to whether or not failure of this assumption will result in biased estimates of general and specific combining ability components of variance. Gilert[5] suggestd that the assumption of independent action of non-allelic genes (no epistasis)

cannot be justified from our knowledge of biochemical pathways on plants. He concluded that such an assumption can only be justified on an empirical basis. Hayman[10] outlined a test for the presence of epistasis based on his graphical analysis of data from diallel crosses. However, reports showed that Hayman's test for epistasis is reliable only if genes are distributed independently in the parents of the diallel. Matzinger and Kempthorne[22] reported that estimate of general combining ability (GCA) variance includes primarily additive genetic variance and portions of epistatic variances and estimate of specific combining ability (SCA) variances includes dominance genetic variance and portions of the various types of epistatic variances when epistatic effects are present in the diallel cross experiment. Thus, the estimates of GCA and SCA are unbiased only if the diallel cross experiment is in the absence of epistasis.

Form a statistical point of view, the concern is the choice of a model with either fixed or random genotypic effects. Griffing[6] developed his analyses in terms of both fixed and random models and suggested that the choice of the correct model depended on the nature of parental materials. Gardner and Eberhart[4] stated that plant breeders and geneticists were usually interested in genetic information about a particular set of parents and should, generally, be using a fixed model in most cases. Hayman[11], in discussing the number of parents required in diallel experiments, concluded that estimates of components of variation could not be reliable estimataes of population parameters unless the number of parents exceeds 10. However, with fewer parents, a fixed model is recommended. In this case, the individual parents and crosses are the main interest, and not a reference population. That is, a large scale diallel cross would use a model with random genotypic effects, a small diallel cross, on the other hand, requires a fixed model.

Form a plant breeding point of view, Gilbert[5] gave a critical evaluation of the diallel cross technique. He concluded that in practical breeding work, its utility to breeders may be exaggerated and information obtained does not appear to be directly relevant to practical breeding work. On the other hand, Johnson[14], through analysis of diallel graph from barley breeding data, argued tdhat compared to other methods available, the diallel cross technique provided a more systematic approach to meet large-scale studies of quantitative characteristics. His results indicated that reliable genetic information could be obtained on dominance and recessiveness, and additional information of the genetic identity of evaluated characteristics in genotypes used would give invaluable guidance to plant breeders

Despite criticism of these assumptions as being unjustifiable and biologically unrealistic [1,5,26] and arguments as to the practical benefit for probems of breeders[5,14], breeders and geneticists continue to use Hayman's diallel analysis. This is probably due to a paucity of alternative methods for obtaining genetic information on quantitative characteristics[1,21,26].

In the presents study, the assumption of homozygous parents was definitely assured because rice is a self-pollinated crop and parental entries used were all pure line cultivars. Although the characteristics studied were all endosperm characteristics which are under triploid genetic control, the gene behavior for these characteristics during meiosis is followed of diploid segregation principle. Thus, the assumption of diploid segregation was met.

The remaining four assumptions have not so easily been justified. Due to expression of endosperm characteristics is under triploid genetic control, the reciprocal differences (including maternal and/or dosage effects, xenia) of these evaluated characteristics were supposedly existed. However, the results obtained from the analysis of variance of diallel tables indicated that no definite evidences for reciprocal differences of these evaluated characteristics were observed. However, the results might be biased by bulking F_2 grains.

The genetic model obtained from the analysis of variance of the diallel tables indicated that the assumptions of independent distribution of genes in the parents and independent action of non-allelic genes appear to have failed for the endosperm characteristics studied. According to Baker[1], failure of the assumption of independent distribution of genes in the parents may result from linkage of genes in the population from which the parents were chosen or from the effects of sample size when sampling the parents. In the present diallel experiment, six rice entries, Rexmont, Guichow, Lemont, Cl 9902, Toro II, and TCS 10, representing three distinct endosperm types, were used as the parents. Rexmont, representing the first major improvement in the U. S. long-grain quality, was developed specifically to satisfy the rice industry's need, and is the forerunner of rice of superior cooking and processing quality. The distinguishing quality characteristics of Rexmont are amylose content 2-4% higher than traditional southern U. S. long-grain cultivars combined with a lower amylographic breakdown viscosity. Guichow, a Chinese *indica* cultivar with high amylose content and low amylographic breakdown viscosity, is a typical short-grain cultivar released from China mainland under a breeding program with high yielding as a priority. Lemont, a leading cultivar in southern rice producing states, represents a high quality traditional southern U. S. Long-grain cultivar, Toro II was a specialty rice produced in limited amount for local markets. Toro II consumers like its clingy cooked texture. TCS 10 also a high yielding *indica* cultivar was released from a Taiwan, ROC. breeding program in 1975 with a high yielding and high quality (in particular low amylose level) as priorities. Generally, Toro II and TCS 10 have a grain size and shape similar to that of the U. S. long -grain type, but cooking and eating behavior similar to those of the U. S. short-and medium -grain types. As Webb and Stermer[34] mentioned, historically and now through planned breeding, specific milling, cooking, eating, and processing characteristics are associated with each grain type of the U. S. rice cultivars. However, this association of grain type with rice quality characteristics definitely not existed in the entries used as parents in this six-parent rice diallel cross. Therefore, among these parents, it might be inferred that the presence or absence of an allele conditioning the endosperm characteristics studied at a particular locus is statistically and genetically independent of the presence or absence of an allele at any other locus. That is, in the present diallel experiment, if the failure of the assumption, independent distribution of genes in the parents, is justified, it should mainly result from the effects of sample size when sampling the parents, as followed by the standpoint of Baker[1].

In addition, Kumar and Khush[15] argued that analyses of genetically heterozygous bulk seed samples on plants provided biased information for the genetic study on endosperm

characteristics, such as amylose content. In this study, genetically heterozygous F_2 bulk grain samples on homogeneous heterozygous, F_1 plants were run for amylose content and amylographic viscosity measurements. This might be another issue in this paper and had to be kept in mind.

In conclusion, compared with other plant quantitative characteristics such as plant height, panicle length, etc., endosperm characteristics differ in three distinct ways, as mentioned above. The lack of both proper genetic model and analysis technology has been an obstacle in studying the genetic behavior of endosperm characteristics. Therefore, establishing a quantitative genetic model and developing a analysis technique based on single grain basis for endosperm characteristics will be of benefit to breeding programs in cereal crops that high grain quality is a priority.

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白米食用與加工品質性狀之 Griffing 與 Hayman 氏全互交變方分析[1]

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摘要：直鏈澱粉含量與澱粉黏度測定值爲白米主要之化學與物理特性，更是稻米食用與加工品質之重要指標性狀，屬胚乳性狀。本研究利用水稻六親本全互交以進行該等性狀之遺傳分析。由於直鏈澱粉含量與澱粉糊黏度測定值之測定無法以單粒法進行，本研究以混合同組合諸遺傳異質 F_1 稻株所得諸遺傳異質 F_2 米粒爲供測樣品，數據經以 Griffing 與 Hayman 兩套方法分析，並按直鏈澱粉含量、澱粉糊高峰黏度、熱糊黏度、冷糊黏度、崩解黏度、回饋黏度與膠體黏度等分別討論。數據顯示七個品質性狀之顯性效應雖存在，但主要受累加性基因所控制。Griffing 與 Hayman 兩套分析顯示七個品質性狀正反交差異均不顯著之事實指出，本研究參試親本符合 Hayman 氏正反交無差異之第二前題。受測各品質性狀之顯性效應除熱糊黏度外，均肇因於單向顯性、基因分布未勻稱所呈之顯性與殘餘顯性等三成份，而熱糊黏度之三類顯性成份中，基因分布未勻稱所呈之顯性值未具統計意義。

關鍵詞：直鏈澱粉含量、澱粉糊黏度測定值、全互交分析、胚乳性狀、白米。

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仙草品系間農藝性狀與化學組成分之比較[1]

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摘要：比較農試所收集九品系仙草的農藝性狀，發現有四品系屬半直立型，五品系爲匍匐型。農藝性狀與產量關係探討發現，葉緣具齒狀，葉形大且長者較高產。礦物元素含量分析，以鉀含量較高，次爲鈣、磷及鎂，且此等元素均以葉含量比莖高，其鐵含量較高者均爲葉色較深綠之A、D及H品系。葉的粗蛋白質、粗脂肪及灰分之分析，仍然發現葉含量均比莖高，但粗纖維含量則較低。無氮抽出物分析結果，以A、B、C及I品系之莖葉間含量差異較微。碳水化合物組成中之游離糖及多醣體含量分析，大部份品系之莖含量均比葉高，但A及B品系之莖與葉含量較接近，因此仙草選種指標除重視葉率外，應一併考慮莖之無氮抽出物含量。單位栽培面積乾草、葉片產量調查與凝膠強度分析，於品系比較試驗結果，A品系兩年平均乾草產量達12,683kg/ha，葉片產量3,328kg/ha最高，次爲 C 品系分別爲9,822kg/ha及3,203kg/ha。凝膠強度A品系爲86.6g/cm^2，C品系爲66.1g/cm^2較高。

關鍵詞：仙草、農藝性狀、化學組成分。

仙草 (*Mesona procumbens* Hemsel) 爲唇形花科 (Labiatae) 之多年生草本植物，在臺灣全境山麓地帶原分佈有野生種，經濟栽培地區多分佈於新竹、關西、苗栗縣三義、銅鑼及水上鄉、番路、竹崎、及中埔等爲主。由於其莖葉煮成茶飲有清熱涼血及降血壓之功效[(1)]，近年商人或食品加工業者，利用其發展多樣化的健康飲料，因此，民間行大面積的栽培。民間栽培的品系，早期均採自野生種馴化而成，但因各地方氣候不同，又仙草本身爲常異交作物，多年雜交演化產生不同生長形態及植物性狀，導致所生產的乾草品質不一，加上栽培技術粗放，產量豐歉變異很大。此作物早期就被學者所重視，因此，有多位學者就其仙草化合物含量及種類、凝膠機制與萃取製凍方法加以研究[(5,6,8,9,10,11,14)]。省農試所於民國74年從關西取４個品系作植期與主成分含量試驗[(2)]，發現關西地方之栽培種爲大葉匍種產量較高，每公頃平均乾草量達6,915kg。移植期探討，則於３月中旬種植較４月中旬佳。主成分中可溶性無氮物 (N. F. E) 含量分析，品系間差異不顯著。民國75年再進一步就不同生長期之主成分含量變化分析[(3)]，發現各品系之乾物量及 NFE 含量，均於移植後180天含量最高，因此，判定仙草最佳採收期以此時間最爲適當。氮肥施用量初步試驗結果，發現每公頃施用140kg量，其乾草產量較高[(4)]。爲了發展此本土性特產，本所乃著手種原蒐集並行觀察及比較試驗，調查其農藝特性、乾草產量及品質分析，以篩選優良品系並命名推廣給本省各地區農民種植。

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材料與方法

一、觀察試驗

供試材料係取自生產區及野生在來種78-S-1(A)等九品系參試，第一年於民國79年3月初育苗，4月2日種植農試所農場，10月19日收穫。第二年乃利用前年宿根苗於4月17日種植，10月21日收穫。試驗方法採 CRD設計，3重複，3行區，行株距1 XO.8m。肥料施用量與方法按農民慣行法，即基肥施用醱酵雞糞10,000kg/ha，化肥全量爲硫酸銨400kg/ha，過磷酸鈣200kg/ha，氯化鉀200kg/ha，作爲二次均分追肥施用，第一次於植後60天，第二次於120天。調查項目分別爲株形、莖的顏色與形狀、莖的絨毛葉背絨毛之有無，以5株取樣調查其平均葉長、葉寬（以心葉下第一節已完全展開之葉片爲主，每株調查10葉）、葉色、葉緣形狀、最長莖長、單株莖葉重量、葉率及乾草產量等。內容物成分分析，係將風乾仙草之莖與葉分別磨粉秤100g，依下列方法分析：

㈠一般成分分析：水分測定以105°C烘乾過夜，秤至恆量計算之。粗蛋白質含量以 semi-Kjeldahl方法測定，氮含量以N%×6.25表示之。灰分含量以600°C灰化法測定之。粗脂肪含量以 Soxhlet 裝置用乙醚抽出18小時測定之。粗纖維含量依 A.O.A.C.[12]方法測定之。無氮抽出物（nitrogen-free extracts）係以100減去前述各項成分之值。

㈡礦物質組成分析：

1. 磷、鈣、鎂、鐵、錳、銅、鋅含量分析：將經過600°C灰化之灰分，以3N鹽酸溶解並以0.2N鹽酸稀釋，用 Whatman No. 41 無灰分濾紙過濾，洗至定量後用感應耦合電漿儀（Inductivitly Coupled Plasama Atomic-Emission Spectrometer, Jobin-Yvon 38 Type III）測定之。
2. 鉀含量分析：將(1)項處理所得到的稀鹽酸溶液以火焰光度計（Flame Photometer, Corning Co. Model 400）測定之。

㈢碳水化合物分析：將仙草葉及莖磨粉之樣本，以80%酒精加熱迴流抽出游離糖後，殘渣以0.75 N HC1加熱迴流兩小時，分解澱粉等多糖體。酒精抽出上澄液，以粉一硫酸法[13]測定糖含量，此含量係以葡萄糖作爲游離糖含量的標準。稀鹽酸分解液亦以粉一硫酸法測定，多醣體含量以澱粉含量爲標準。

二、品系比較試驗

以上年品系觀察園之母株行宿根培養，民國81年2月初扦插育苗，3月31日種植本田。試驗設計採 RCBD，4重複，行株距1.4×0.9m，3行區，每行種10株。基肥施用醱酵雞糞5,000kg/ha，化肥全量爲複合肥料1號（N20:P_2O_5 5:K_2O 10）700kg/ha，於植後60天及90天等量分施一次，10月5日收穫。調查項目分別爲平均單株乾株重、乾葉重、葉率、公頃乾葉量、乾株重、始花期（日數）及凝膠強度等。第二年於4月19日種植，10月14日收穫，試驗及調查方法與前年同。凝膠強度測定，乃將仙草汁以水稀釋爲全可溶性固形物之1.0 Brix 溶液，加熱煮沸後，再添加2%澱粉（先用水溶解），靜置冷卻，待其成膠凍後開始測定。測定儀器爲Fudoh Kogyo Co. LTD 之物性測定儀（Rheometer, NRM-2010 J-CW），測定條件爲感頭1 kg，4號套頭，直徑5 mm，載物台速度每分鐘30cm/Min。

結果與討論

一、仙草植物性狀之調查

仙草爲熱帶地方山野自生的一年或越年生草本植物，全株具有絨毛蔓生，莖在基部生有不定根多

爲匍匐性，上部則次第直立；葉有葉柄，葉身有長橢圓形、短橢圓形、心形等；葉片有大有小，葉緣有鋸齒狀齒牙。秋天由莖頂上抽出花莖，著生多數紅紫色小花。在臺灣，仙草自生於全境平原山麓，高30—60公分以上。依據楊氏園藝植物大名典的記載仙草全屬（*Mesona blume*）約有十種，分佈於東南亞、中國、臺灣；臺灣自產有一種*Mesona procumbens* Hemsel[7]。胡等在省產之物種上約分爲四種類，即小葉匍匐種、小葉半直立種、大葉匍匐種及大葉半直立種[2,3]。表 1 所示的九種仙草品系，係收集來自本省西半部之產區與山麓。其農藝特性經觀察發現九品系之莖全部爲方形，株形則可分爲半直立與匍匐兩種，葉緣分爲深、中鋸齒及淺齒狀等，葉色有深綠與淺綠，葉片有大有小。僅有 H 與 I 兩品系，莖及葉背均被絨毛。嘉義水上鄉及阿里山達邦地區所產的，至目前大都以半直立種爲主。

表 1. 不同仙草品系植物性狀之比較

Table 1. Comparison of plant characteristics among nine hsian-tsao strains.

Strain	Plant type	Stem color	Stem pubescence	Leaf shape	Leaf length (cm)	Leaf width (cm)	Leaf color	Leaf dentation	Origin
78-S-1(A)	semi-erect	purple	long, sparse	ellipsoid	3.9	1.8	dark-green	medium	Shuishang, Chia-I
78-S-2(B)	semi-erect	pale purple	short, sparse	ellipsoid	4.2	1.8	pale-green	medium	Shuishang, Chia-I
78-T-1(C)	runner	pale purple	short, sparse	ellipsoid	3.9	2.2	pale-green	medium	Tunglo, Miaoli
73-K-1(D)	runner	pale purple	short, sparse	ellipsoid	2.5	1.7	dark-green	medium	Kuanhsi, Hsinchu
73-K-2(E)	runner	pale purple	short, sparse	ellipsoid	4.2	2.4	pale-green	medium	Kuanhsi, Hsinchu
73-K-3(F)	runner	pale purple	short, sparse	ellipsoid	2.8	1.5	pale-green	shallow	Kuanhsi, Hsinchu
78-K-4(G)[z]	runner	pale purple	short, sparse	ellipsoid	3.5	1.9	pale-green	deep	Kuanhsi, Hsinchu
73-K-5(H)	semi-erect	purple	short, sparse	ellipsoid	3.0	1.9	dark-green	shallow	Kuanhsi, Hsinchu
78-A-1(I)	semi-erect	purple	short, dense	oval	3.9	2.3	pale-green	shallow	Alishan, Chia-I

[z] A currently cultivated in Kuanhsi area (Hsinchu).

二、品系之農藝性狀觀察及產量調查

經兩年栽培觀察發現，每公頃平均乾草產量除 A 品系表現較穩定外，餘各品系之第一年栽培表現均比第二年佳（表 2）。之中，如 D、F、G、H四品系平均產產量較低，從葉性狀上可發現其葉形均較小、短橢圓、光滑；且 F 及 H 品系其葉緣均屬淺齒狀，換言之，葉緣淺齒狀的仙草品系，其乾草產量似比鋸齒狀較深之品系低，因此從植物性狀上欲篩選乾草產量較高之品種，似可選葉較大，葉形長橢圓，葉面縐縮且葉緣呈鋸齒狀較明顯者（medium dentation）爲佳。另外，葉率調查，各品系表現與乾株產量相反，即第一年均比第二年低，此因第二年各仙草品系生長受氣候及連續利用旱地種植之影響，莖蔓生育未如第一年充分伸展，以致生長勢較差而顯現葉密生成蔟狀。

仙草自古以來其用途大都是做仙草凍銷售，仙草凍品質之好壞在於乾株之凝膠性。楊氏[6]分析仙

草根莖葉所含膠質之凝膠性時發現葉大於莖，本試驗以此九品系材料製仙草凍時，發現各品系取同量莖與葉蒸煮時，葉的凝膠情形有高出莖之趨勢。因此在品種的選拔上，若以製仙草凍爲目的時，除了單位面積葉生產量要高外，尙需選擇仙草生育後期不易落葉的品種。從其單位面積葉生產量調查結果，較高的品系發現依次爲A、E、C與 B 品系。因此，此等品系若能注意適時採收，確實是本省生產優良仙草凍的優良品種。

表 2. 不同仙草品系之農藝作狀表現

Table 2. Performance of agronomic characteristics of nine hsian-tsao strains in 1990 and 1991 cropping.

Strain	Cane length (cm)		Leaf weight (g/pl.)		Stem weight (g/pl.)		Whole plant weight (g/pl.)		Leaf wt. /whole pl. wt.(%)		Dry plant weight (kg/ha)	
	1990	1991	1990	1991	1990	1991	1990	1991	1990	1991	1990	1991
A[z]	107.3	82.1	75.0	168.7	206.3	189.6	313.6	358.3	23.9	48.5	4,356	4,976
B	101.1	73.2	68.4	118.7	155.0	114.6	256.1	233.3	27.2	50.9	3,557	3,240
C	89.5	59.1	105.7	107.3	255.4	61.3	314.7	168.6	35.3	67.1	4,370	2,324
D	96.8	71.2	80.3	94.7	178.2	61.3	275.0	156.0	30.2	60.7	3,819	2,166
E	93.2	53.0	125.0	96.7	255.4	70.0	348.6	166.6	35.5	61.5	4,842	2,314
F	71.6	59.4	93.6	93.3	183.6	58.0	255.3	151.3	36.7	63.8	3,545	2,101
G	66.0	55.7	74.6	98.7	164.6	64.0	230.6	162.6	33.1	61.2	3,203	2,258
H	78.7	58.2	92.0	92.0	150.8	64.0	229.5	156.0	41.0	60.4	3,188	2,166
I	74.7	70.0	61.3	119.3	165.9	118.3	240.3	237.6	27.5	51.3	3,337	3,300
LSD5%	24.0	ns	ns	ns	ns	7.65	ns	ns	7.0	11.8	ns	ns
1%	33.0					—			9.6	16.3		

z See the Table 1 description for strain.

三、不同仙草品系之礦物組成分含量分析

由於仙草屬地區性作物，一般成分分析均針對粗蛋白、粗脂肪、粗纖維及無氮抽出物等，此等成分尙有部份資料可參考，而有關灰分的組成分析，尙未有人硏究。圖 1 所示不同品種仙草葉與莖的礦物質組成比較（每百公克中含量），可發現仙草莖葉以鉀含量佔最多（葉平均3,805mg，莖平均2,571mg），次爲鈣（葉平均794mg，莖平均594mg）、磷（葉平均554mg，莖平均252mg）及鎂（葉平均255mg，莖平均136mg），其中除了錳以外，各種礦物質元素含量均以葉高出莖甚多，尤其是葉的鐵平均含量達212mg，高於莖平均含量40mg之數倍。若將鐵含量與品系農藝性狀對照，則葉色深綠色的A、D、H品系其葉鐵含量則較高。一般而言，深綠色蔬菜也比淺色蔬菜鐵含量高，可見葉色深淺與鐵關係密切。

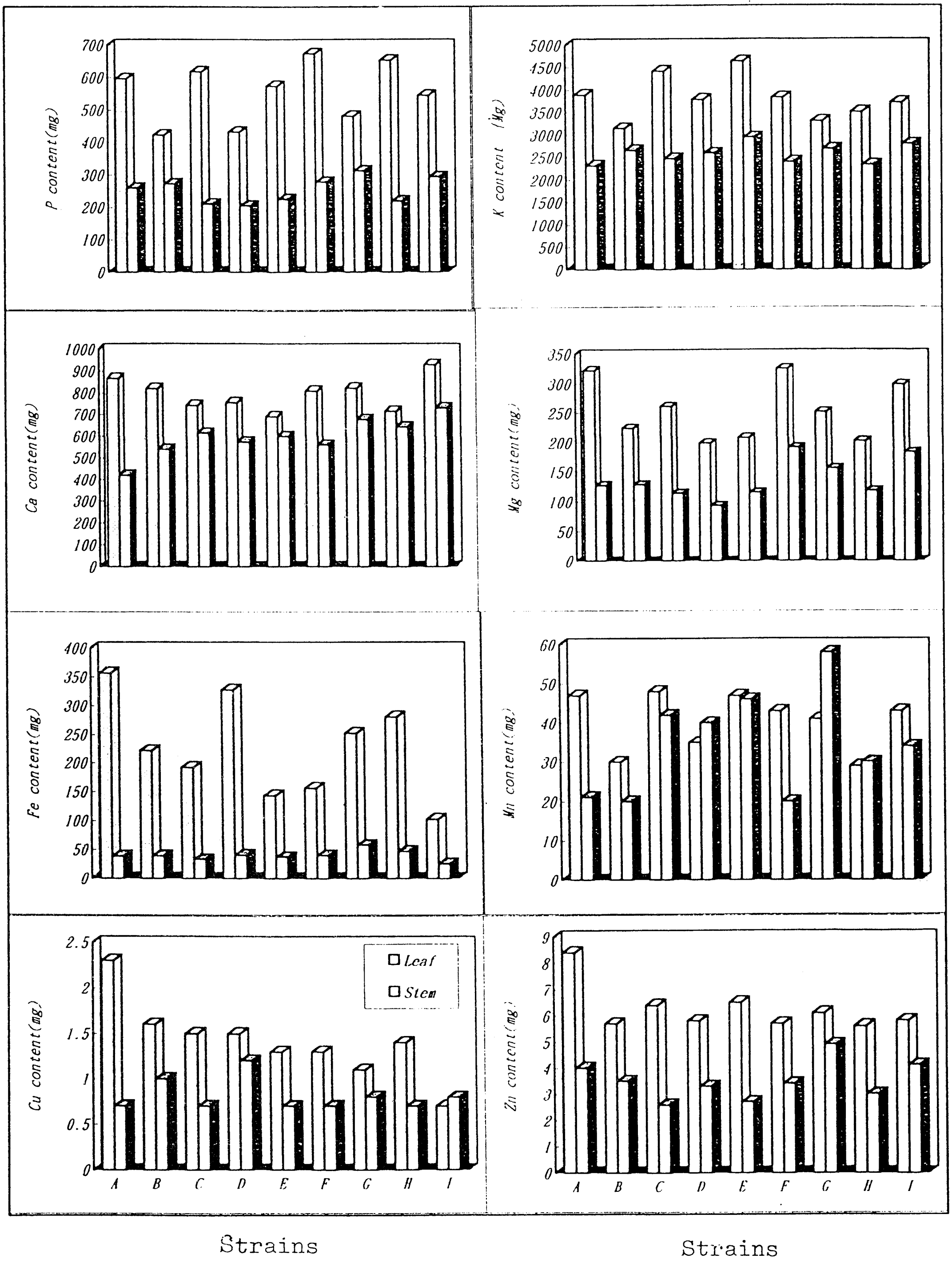

圖 1. 不同仙草品系之礦物組成分含量分析

Fig. 1. Comparison of the contents of mineral element in stem and leaves for nine hsian-tsao strains.

四、仙草不同品系之一般成分含量分析

不同仙草品系之一般成分含量分析，依據楊氏分析結果[6]，莖粗蛋白質含量爲2.57%，粗脂肪爲2.24%，粗纖維爲44.79%，無氮抽出物(N. F. E)爲41.37%，灰分爲9.02%；葉粗蛋白質含量爲10.23%，粗脂肪爲7.89%，粗纖維爲16.2%，無氮抽出物(N. F. E)爲48.8%，灰分爲16.8%。本試驗所參試之九品系，經分析發現前述成分莖平均含量各爲3.87%、2.26%、41.95%、43.66%及8.27%；葉平均含量依次各爲13.85%，9.32%，15.73%，43.95%及17.15%，所得之數據與楊氏之分析頗爲相近。品系間之各成分含量比較，以較重要之粗蛋白質、粗脂肪及無氮抽出物三項成分比較，前二者成分莖葉間含量差異較大，而無氮抽出物則莖葉間之含量較接近（圖2），尤以A、B、C及I品系莖葉間之N、F、E含量差異較小，據楊氏報告[6]N.F.E. 含量高，則 pectin 含量亦高。另指出仙草液凝膠機制乃由適量澱粉與適量多糖體分子所扮演，且凝膠網主體爲 Fraction C, N. F. E. 含量中大部份爲多糖體，因此 N. F. E. 含量高低似與凝膠強度有關，如此，選擇優良仙草品系以此特性爲選種指標應頗有意義。

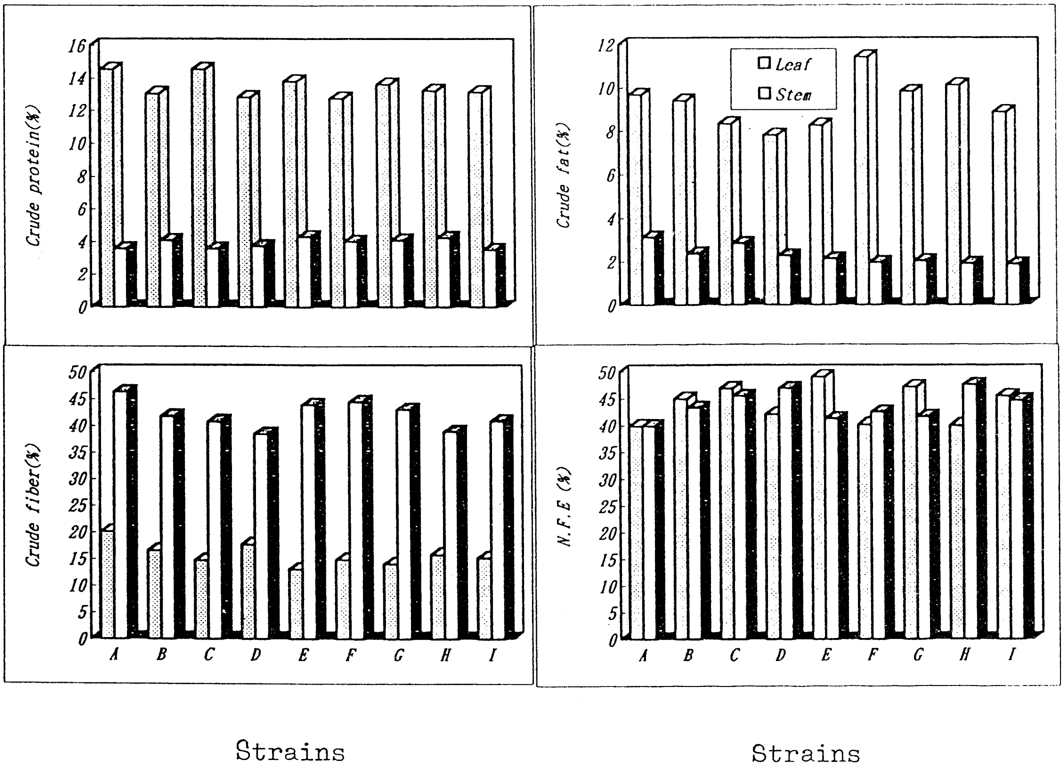

圖 2. 不同仙草品系之一般成分含量比較（以乾物重計）

Fig. 2. Comparison of the chemical composition for nine hsian-taso strains(dry basis).

五、不同仙草品系之碳水化合物含量分析

一般成分分析所得到無氮抽出物中包含了游離糖，如單糖、雙糖、寡糖（oligo-saccharide），多糖體（polysaccharide）如澱粉、果糖聚醣（fructosan）、木聚醣（xylan）、甘露聚醣（mannan）等，還有果膠質（pectin）、植物膠（gum）、色素、粘質物、酸類、配醣體等許多性質不同的成分。其中最主要的當然是碳水化合物，即通稱的醣類它包括游離糖、糖醇與聚醣等。粗纖維成分中雖然也含有碳水化合物如纖維素、半纖維素等，但是這兩種成分和木質素（lignin）同屬結構性成分，其不溶於稀酸、稀鹼的部份，係歸入粗纖維中而不計入碳水化合物內。

圖 3 所示不同品種仙草風乾物葉、莖的游離糖、多醣體及總碳水化合物（total carbohydrates），即游離糖與多醣體總和含量之比較，獲知無論是游離糖（A、B、F、G及 H 品系除外）或多醣體含量大都以莖較葉高出甚多，因此一般以葉率作爲仙草選種指標、值得商榷，似亦應考慮其莖之所佔比例。至以總碳水化合物含量之變化未與 N. F. E. 含量呈一致，此可能因結構性成分存於纖維素或半纖維素未析出所致。

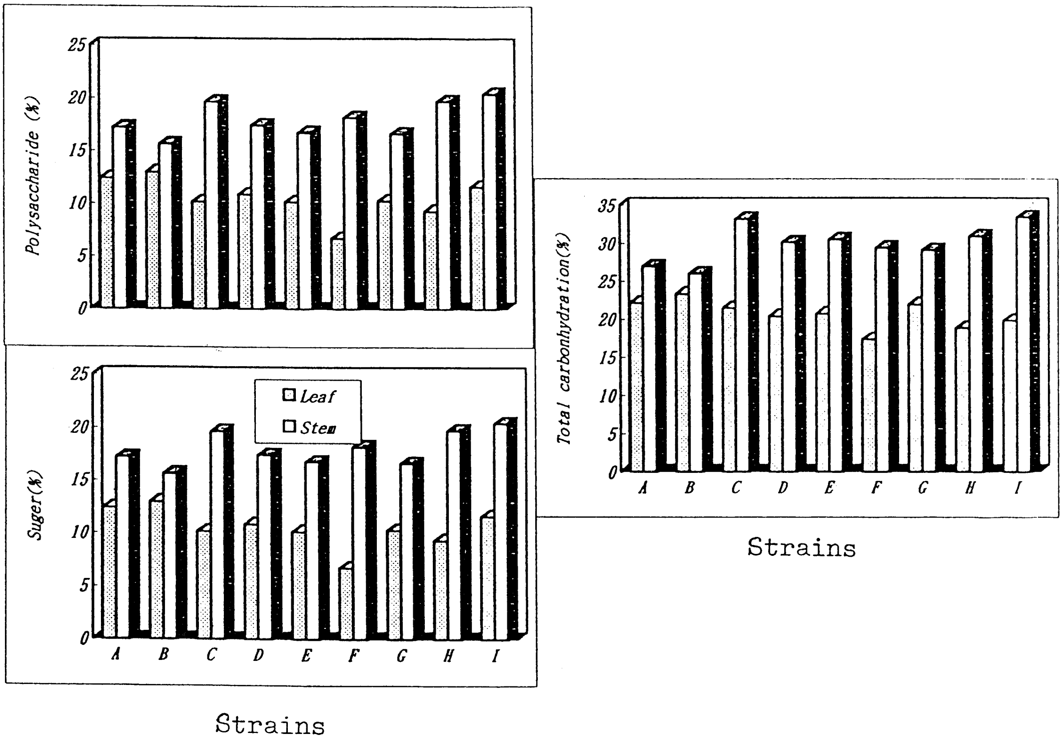

圖 3. 不同品系仙草碳水化合物含量之比較

Fig. 3. Comparsion of carbohydrate contents for nine hsian-taso strains.

六、品系比較試驗

爲進一步瞭解該等品系的表現，乃仿民間慣行種植及管理方法，與根據肥料試驗所獲得施用量，每公頃氮肥增施至140公斤，希冀安排較佳的生長條件以利仙草表現而作篩選，因此採用同樣材料進行品系比較試驗，其結果從表 3 之數據可發現，民國81年各品系乾草產量均比82年所生產較高，此乃82年仙草生育期間適遇乾旱期，久旱不雨，仙草生長不良，甚至有些品系發生疑似萎凋病無從收穫所致。但就其乾草及葉生產量而言，所參試九個品系中A品系表現最穩定，第一年乾草量達13,385kg，葉量達3,266kg；第二年分別爲11,980kg及3,390kg。其次爲 C 品系，第一年乾草量達11,874kg，葉量達3,906kg；第二年分別爲7,770kg及2,500kg。除此之外，凝膠強度測定發現，A品系在所有品系中表現最優達86.6g/cm^2，C 品系之凝膠強度66.1g/cm^{2}雖不及A品系，但其葉率含量高，且株型屬匍匐型優美，生長晚期全株仍青綠不變褐棕色，農民對其頗有偏好性，因此，此兩品系被中選晉級作爲區域試驗品系。

表 3.　不同仙半品系農藝性狀之比較與產量表現

Table 3. Performance of agronomic characteristics and dry plant yiel for nine hsina-tsao strains in a comparative test

Strain	1992 Dry plant weight (kg/pl.)	1992 Leaf wt. /whole plant wt. (%)	1992 Dry plant wt. (kg/ha) Whole plant	1992 Dry plant wt. (kg/ha) Leaf	1992 Gel forming strength (g/cm^2)	1993 Dry plant weight (kg/pl.)	1993 Leaf wt. /whole plant wt (%)	1993 Dry plant wt. (kg/ha) Whole plant	1993 Dry plant wt. (kg/ha) Leaf
A[z]	1.807	24.40	13,385	3,266	86.6	1.51	28.3	11,980	3,390
B	1.396	25.70	10,340	2,657	56.3	0.51	23.1	4,040	930
C	1.603	32.90	11,874	3,906	66.1	0.98	32.2	7,770	2,500
D	1.205	31.30	8,926	2,794	54.3	0.40	39.9	3,170	1,260
E	1.164	35.20	8,622	3,035	57.0	—	—	—	—
F	0.899	34.10	6,659	2,270	65.1	0.74	21.2	5,870	1,240
G	1.105	35.20	8,185	2,881	68.9	—	—	—	—
H	1.000	30.20	7,400	2,235	73.6	0.82	17.6	6,500	1,140
I	0.737	30.50	5,459	1,665	47.0	—	—	—	—
LSD 5%	0.453	5.45	3,356	403	15.0	0.30	5.6	2,380	133
1%	0.625	7.50	4,630	555	21.8	0.46	7.7	3,650	281

[z] See the Table 1 description for strain.

結　論

本所近年來在農委會經費支持下，進行仙草育種工作，由上述試驗結果發現已有初步成果。即已分別篩選出78-S-1(A)及78-T-1(C)等二品系不論在乾株及乾葉產量與凝膠強度均有優異的表現，目前正依據此結果進行區域試驗及栽培技術改進試驗，進一步詳加調查其適應性及產量穩定性中，希望不久能推廣給農民栽培。仙草最普遍的加工方式有仙草茶及仙草凍，仙草茶重香氣及滋味，仙草凍則重凝膠性。在本試驗中發現仙草葉與莖成分大不相同，其中有關糖類方面反而莖組織中含量比葉高，此結果提供一項訊息，即仙草選種指標不能僅依存葉率，似乎莖凝膠強度之高低亦應考慮，且香氣的濃淡也不能忽略，此等均爲影響仙草凍及仙草茶品質的要素，同時應再進一步探討莖與葉中之 Fraction C 含量，是否莖組織中此成分含量較低而影響其凝膠性。

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Comparison of Agronomic Characteristics and Chemical Composition among Different Hsian-tsao Strains (*Mesona procumbens* Hemsl)[1]

Min-Fu Hu[2], Huey-Ing Liu[3], Chien-Liang Chu[3] and Sin-Yie Liu[2]

Summary

The agronomic characteristics of 9 different hsian-tsao strains collected by TARI were compared, Results found that 4 strains are semi-erect type and the rest are runner type. Results from studing on relationship between agronomic characteristics and dry plant yield found that line with large leaf blade and medium dentation in leaf margin has higher dry plant yield. Analyzing the contents of mineral elements, the results shown that highest rate in leaves and stem is potassium, following by Ca, P and Mg in order, also the contents in leaves were higher than those in stem. Otherwise, it also found that A, D and H strains with higher iron content had dark green leaves than those of other strains. Comparison in the chemical composition of 9 different hsian-tsao strains, it was found that the contents of crude protein、crude fat and ash were higher in leaves for all strains, but crude fiber was less than in stem. The contents of nitrogen-free extracts in leaves were found little differences comparing with those in stem for A、B、C and I strains, The contents of carbohydrate were higher in stem than that in leaves. Among carbohydrate composition, the contents of sugar and polysaccharide in leaves had little differences comparing with those in stem for A and B strains. Therefore, it can not consider the leave percentage as the only index, the contents of nitrogen-free extracts in stem should be consider too for selecting in hsian-tsao. Results found that the average yields of dry whole plant and leaves for A and C strains were 12,683 an4d 9,922 kg/ha, and 3,328 and 3,203 kg/ha respectively, A and C strains in gel formation strength with 86.6 and 66.1 g/cm2 also had good performance than that of the other strains.

Key words : Hsian-tsao strains, Agronomic characteristics, Chemical composition.

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低需冷量桃樹果實發育所需的熱量時間[1]

宋家瑋[2]　歐錫坤[2]

摘要：估算本省霧峰地區11個低需冷量桃栽培種果實發育的熱量時間（degree days, °Cd，以10°C爲基本溫度，從盛花期至第一次商業性採收的積溫）與果實發育日數（FDP）。結果顯示：桃的成熟時間是依開花早晚與果實發育日數的長短而定，其中早熟種之果實發育日數爲83～98天，熱量時間爲821～1,066°Cd，中熟種之果實發育日數爲109～128天，熱量時間爲1,022～1,264°Cd，晚熟種之果實發育日數大於130天，熱量時間大於1,523°Cd。

關鍵詞：桃、低需冷量、果實發育日數、熱量時間、成熟期。

早於18世紀就有人將植物生長速度與溫度間的關係，用方程式來表示[27]，此一基本關係也曾被利用於結構性的模式，以便預測植物的反應。若以高於某一基本溫度所得的有效溫度來衡量，則完成一種生育過程所需的熱量稱之爲熱量時間（thermal time），又稱積溫，其單位爲度日（degree-days）或熱量單位（heat units）[12]。此一線性關係可寫爲 $Q=(T-Tb)t$。Q 爲熱量時間（°Cd），T 爲有效溫度（°C），Tb 爲基本溫度（本試驗採用 10°C），t 爲時間（天，d）[13]。

熱量時間已多用於預測許多果實的成熟日期[6,8,9,26]及一些桃樹的栽培種[7,10]上。熱量時間可以用很多種方法來計算，但任何方法預測結果的準確性均有賴於事先精確地決定基本溫度[5,11]。桃樹都採用10°C爲基本溫度，而果實生長的熱量時間通常利用生育時期的日平均溫來計算，因爲此一氣象資料不但獲得容易，而且大部分生育過程與平均溫度的關係較任一特殊時間的溫度爲密切[23]。

桃的成熟時間是依開花時期與果實發育日數（fruit development period, FDP）的長短而定，開花時間是受每一栽培種的低溫需求量所調節，以及低溫滿足後的熱量單位累積值而定，果實發育日數的估算是從盛花期那天開始，至果實第一次商業性採收的日期爲止，其日數則依品種而異，受每一品種從盛花至成熟的熱量累積值所調節[13]。Baker 與 Brooks[6] 也曾採用一熱量時間的系統，評估杏（apricot）與歐洲李（prune）果實的成熟時期。

Black 認爲美國新澤西州 4 月與 5 月的溫度，可以影響桃樹果實發育日數的長短[24]。Weinberger 發現，'Elberta' 桃樹在美國喬治亞洲的 Fort Valley 開花後50天內的最高溫度，預測果實發育日數最爲可靠[24]。Topp 與 Sherman[24] 在澳大利亞調查22個桃樹栽培種在13個不同地區與果實生長期間之月平均溫度的關係，發現果實發育期間之月平均溫度每減少 1 °C可以使果實慢 5 天成熟，而開花後二個月以內的溫度對決定果實發育日數最爲重要，可用迴歸方程式來預測各不同地區相對的果實發育日數。

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果樹育種家常以果實發育日數和果實發育所需的熱量時間的多寡，來判別各品種間成熟期的早晚，做爲篩選早熟種與晚熟種的依據。生產者亦能利用此一預測訊息，及早計畫採收的勞力與包裝器材；承包商、運銷商、與包裝場也可藉此訊息及早安排他們的作業。本試驗目的在於瞭解低需冷量桃品種開花結果習性，並計算果實發育日數與所需的熱量時間，作爲排列各不同栽培種成熟期早晚的依據。

材料與方法

本試驗供試材料爲種植於臺灣省農業試驗所的桃樹品種保存園，計有國外引入的15年生低需冷量桃樹栽培種‘Okinawa’、‘Flordared’、‘Premier’、‘TropicSweet’、‘Tropic Snow’、‘Flordagold’；以及本地種的‘苦桃’、‘鶯歌桃’、‘早生福州大桃’及經過初選擇優汰劣而來的6年生優良雜交後代‘7612’、‘7669’等，共計11個品種。

從1995年11月29日花芽萌發之初開始，每隔7天以計數器調查一次田間品種保存園各栽培種的開花數與著果數，至3月14日花期結束爲止；每一供試品種調查2株，取其平均值。始花期（start bloom）的判定爲約有5％的花朵開放，盛花期（full bloom）的判定爲60～80％的花朵開放。當芽體膨大至可看見粉紅色花苞時，爲計算開花數的標準。當花瓣脫落，小果出現時爲計算著果數的標準。由於花芽萌放之初，我們並無法預測全株有多少的開花數量，所以用計數器每星期調查一次供試材料的開花數目與著果數，調查至花期近尾聲，葉片與小果陸續出現爲止，然後再以調查期間，每品種所表現的最多的開花數目（包括著果數）爲分母，每星期所調查的開花數（包括小果）爲分子，可得各調查時期之花朵開放的比率，從而判定開花過程中始花期（5％以上開花）與盛花期（60～80％以上開花）的發生點[4]。在桃第一次生理落果後，於4月10日再調查一次著果數，以著果數除以最高開花數決定其著果率，每一栽培種調查3株。

桃果實發育日數的計算方式是自盛花期那天開始，至果實第一次商業採收的日期爲止，故在果實成熟時調查其經濟採果期，以判定果實發育日數。各栽培種果實發育所需的熱量時間計算方法，則是從盛花期開始至果實開始商業性採收的日期爲止，以自動溫度記錄器記錄每天24小時的日夜溫度，求其平均值後，再扣除基本溫度10°C的累計總值。

結果與討論

一、花期調查

低需冷性桃栽培種的花期調查，是爲界定桃樹栽培種的始花期、盛花期及開花行爲，利用每品種在開花期間所表現的最大開花數目（包含著果數）除以每星期所調查的開花數（包含小果），判定約有5％的花朵開放時爲始花期，60～80％的花朵開放時爲盛花期[3]，其調查結果詳見表1。

就開花數與開花時間而言，除‘苦桃’至1996年1月5日、‘Flordagold’及‘7612’至1月12日才開花外，其它品種均在12月底即已開花。經計算始花期以‘Okinawa’的1995年12月29日最早，‘Flordagold’、‘TropicSweet’及‘TropicSnow’爲1996年1月5日，‘苦桃’爲1月26日，其餘則爲1月19日，故始花期除‘Okinawa’較早，‘苦桃’較慢外，其餘均集中在1月上、中旬。盛花期則以‘Okinawa’的1月26日最早；‘Flordagold’、‘TropicSnow’爲2月2日其次；‘鶯歌桃’、‘TropicSweet’爲2月8日，‘Premier’、‘7612’、‘早生福州大桃’、‘苦桃’爲2月15日，而‘Flordagold’及‘7669’則爲2月23日較慢（表1）。

1986年 Munoz 等[13]認爲桃開花的時間受該栽培種的低溫需求量，以及低溫滿足後的熱量時間所節制；Sherman 和 Rodriquez-A[19] 在1987年的報告也指出，不同低溫需求的桃生長在高緯度地區，其開花甚整齊，花期通常多集中在3至5天內。這些品種都能在冬天內滿足其低溫需求，且在

表 1. 低需冷量桃栽培種花期調查

Table 1. Investigation on blossom of low-chill peach cultivars

Cultivar	Blooming dates and number of opening flowers											
	1995	1996										
	12/29	1/5	1/12	1/19	1/26	2/2	2/8	2/15	2/23	2/29	3/7	3/14
Okinawa	81.5*	79	166.5	339.5 (18.5)	539.5** (19)	481 (73.5)	606 (156.5)	663.5 (300)	553.5 (364)			
Flordared	15	37.5*	114	187.5 (22.5)	231.5 (38)	329** (62)	493 (143.5)	298.5 (119.5)	366.5 (299.5)			
Premier	1	2	6	67 (1)	76.5 (4)	135 (16.5)	159 (20.5)	289.5** (55)	421.5 (147.5)	378.5 (145.5)	327.5 (258.5)	
TropicSweet	5	17*	27	37.5 (6.5)	80.5 (22.5)	119 (49)	201** (57)	236.5 (72.5)	226 (119)	207.5 (156)		
TropicSnow	24	62.5*	141.5	301 (14)	366 (24.5)	603** (144)	666 (164)	701.5 (262.5)	691 (378.5)			
Flordagold			1.5	13.5*	20	30.5	44.5 (6)	57 (9)	105.5** (21)	130.5 (38)	86 (30.5)	69.5 (31)
Tzao-sheng-fu-jou-dah-taur (早生福州大桃)	140	156	153	688* (27)	970 (45)	1,166.5 (109)	2,205.5 (294.5)	2,765** (737)	3,772 (1,248)	2,728 (1,480.5)	2,418.5 (1,900.5)	
In-ge-taur (鶯歌桃)	29	50.5	69.5	239* (7.5)	587 (9)	815 (34)	2,215.5** (83.5)	3,004 (157)	3,270.5 (758.5)	2,215 (771)		
Kuu-taur (苦桃)		3	17	140 (1)	636* (3)	836 (27)	2,731 (42)	4,065** (208)	6,576 (1,388)	5,160 (2,482)	5,817 (4,964)	
7612[z]			4.5	48* (1.5)	68 (0.5)	133.5 (1)	229.5 (14.5)	289.5** (34)	436.5 (190.5)	393 (207)		
7669[y]	6.5	7	13.5	41* (0.5)	48 (0.5)	122.5 (5.5)	205.5 (14)	266.5 (22)	436** (72)	467.5 (105)	300.5 (202)	

* Start bloom : more than 5% of flowers opening, number of fruits setting given in the parentheses.
** Full bloom : 60~80% flowers open and considered as the date of rest completion.
z,y New selections.

春暖時期同時累積熱量時間，所以開花表現甚為整齊。然而當這些品種在低緯度較溫暖地區生長時，花期則通常會分散達 2 至 5 週，其原因有二：(1)當冬天的氣溫在滿足低溫需求和積溫的有效溫度上下浮動時，低需冷量品種因低溫需求較高需冷量品種早滿足而先累積積溫。(2)一些高需冷量品種因低溫不足在無法滿足其低溫需求下而延遲發芽。故品種的花期是隨其低溫需求量的多少而變動，需冷量低的品種先開花，需冷量高的品種晚開花[20]。本試驗的開花調查情形和以上結論有相似的情形，‘Okinawa’ 的低溫需求量為 75CU[3,4,18]，故開花較早；‘Flordagold’ 為 325CU[20,22]，故開花較慢，其餘介於 100~200CU[4,14,15,17,21] 之間故開花居中。若以盛花期比較，最早花的 ‘Okinawa’（75CU）和最晚花的 ‘Flordagold’（325CU）相差有四週。這一現象常會造成一些育種工作上的困擾，如以低需冷量的品種為父本，高需冷量的品種為母本，即必須儲存花粉才能順利進行人工雜交授粉工作。美國佛羅里達州進行桃的育種作業時，其最早花品種（<100CU）和最晚花品種（≒500 CU）相差約五週[19]。在本試驗中，雖然 ‘7669’（175CU）[4] 的盛花期和 ‘Flordagold’（325CU）相同，但由開花數和結果數上比較，‘7669’ 顯然皆高於 ‘Flordagold’，顯示臺灣霧峰地區的平地的低溫量尚未滿足 ‘Flordagold’（325CU）的需求。此結果和1989年 Rouse[16] 所發表的結論吻合，即「亞熱帶種植的桃樹栽培種，低溫需求量通常少於 200CU」，1992年歐氏[4]也印證了 Dr. Rouse 的結論。

就著果情形而言，在始花期之前的調查除‘苦桃’有一粒著果外其他品種並無著果，‘Flordagold’ 其花期最慢而著果也慢，在2月8日的調查始有著果外，其他品種不論始花期早晚在1月19日的調查均有著果，此顯示各品種早期開花並不容易著果，可能與早期開花時霧峰地區的氣溫較低，影響授粉著果有關。以‘Okinawa’ 爲例，自12月29日即有數目不少的花朶開放，至1月19日的調查才有著果，1月26日爲盛花期，著果數才19個，而大部分著果出現在盛花期後的調查，而其它品種亦有類似情形變化（表1），此與氣溫回升，開花數目增加，有益授粉著果有關。

二、最高開花數與著果率調查

在最高開花數方面，本地種的‘早生福州大桃’及‘鶯歌桃’最多（表2），和其它品種有顯著差異，‘Flordagold’ 的花數最少。在著果數目方面也以‘早生福州大桃’、‘鶯歌桃’最多，和其它品種差異達到顯著水準，‘TropicSnow’、‘7612’、‘Premier’、‘Okinawa’ 居次，仍以‘Flordagold’ 著果最少，此和霧峰冬天對其開花所需的低溫需求量不足有關，導致花數及著果數不多。以最高開花數和著果數作相關性分析時，以‘Okinawa’ (r=0.473) 最低，‘TropicSnow’ (r=0.832) 及‘鶯歌桃’ (r=0.849) 稍低，其它均在 r=0.95 以上（表2），顯示最高開花數和著果數間有明顯的正相關性，即開花數目多則著果數也多。

表 2. 不同桃栽培種最大開花數與著果調查

Table 2. Investigation on blooming in relation to fruit setting of peach.

Cultivar	Mean flower number[z]	Mean fruit number[y]	Fruit set (%)	r(n=3)[x]
Okinawa	659 cd[w]	274 bcd	42.4 bcd	0.473
Flordared	387 d	183 d	48.8 bc	0.999
Premier	510 cd	290 bcd	52.9 b	0.999
TropicSweet	273 d	152 d	56.3 b	0.978
TropicSnow	1,132 c	518 b	50.0 bc	0.832
Flordagold	153 d	51 d	35.5 cd	0.983
7612	615 cd	486 bc	82.7 a	0.999
7669	467 cd	210 cd	44.7 bcd	0.949
In-ge-taur（鶯歌桃）	2,480 b	1,121 a	45.1 bcd	0.849
Tzao-sheng-fu-jou-dah-taur（早生福州大桃）	3,724 a	1,190 a	31.9 d	0.954

[z] The highest number of blooming for a tree. Each value is the mean of 3 observations.
[y] The number of fruit set on April 10, 1996.
[x] Correlation coefficients of the high bloom number and fruit set.
[w] Significant at 5% level.

以4月10日的著果數除以最高開花數所得的著果率，以‘7612’ 的82.7%最高，顯示‘7612’ 的開花著果有效性優於其它品種。‘Flordagold’ 及‘早生福州大桃’其開花有效率較低。‘早生福州大桃’雖然著果數多，但由於花數也多，故其有效著果率較低；而 ‘Flordagold’ 則原本花數就少，著果更少，故其著果率也低，顯然其不適合在臺中平地上開花著果。1992年歐氏也指出，臺中地區冬天低溫量變化很大，當有些年份低溫單位較少甚至爲負値時，‘Flordagold’ 的生育就不如理想。本省平地或淺山坡地區欲發展高品質水蜜桃宜以低溫需求量在 325CU（‘Flordagold’）以下栽培種爲主要考量對象。由上述可知本地種的‘早生福州大桃’及‘鶯歌桃’，在開花、著果上，較其它品種爲多，而其它品種除‘Flordagold’ (325CU) 因低溫需求不足，導致花果數目不多外

，差異並不明顯，顯示這些引入的品種和選拔品系（≦200CU）對臺中平地的風土有相當的適應性。

三、果實發育日數和果實發育所需的熱量時間

有很多種方法可以用來計算熱量時間，本試驗採用 10°C 爲基本溫度，熱量時間的估算方程式可寫爲 $Q=(T-Tb)t$。Q 爲熱量時間（攝氏 degree-day）；T 爲有效溫度（°C），Tb 爲基本溫度，t 爲時間（天）。1995年11月至1996年 6 月本省臺中地區月平均溫度變化如圖1. 表示，以12月最低平均溫度10.7°C與二月平均溫度15.8°C爲最低。於本試驗利用生育時期的日平均溫來計算熱量時間，因爲此一氣象資料不但獲得容易，而且大部分生育過程與平均溫度的關係較任一特殊時間的溫度爲密切[23]，其果實發育日數與所需熱量單位經計算如表 3 所示。

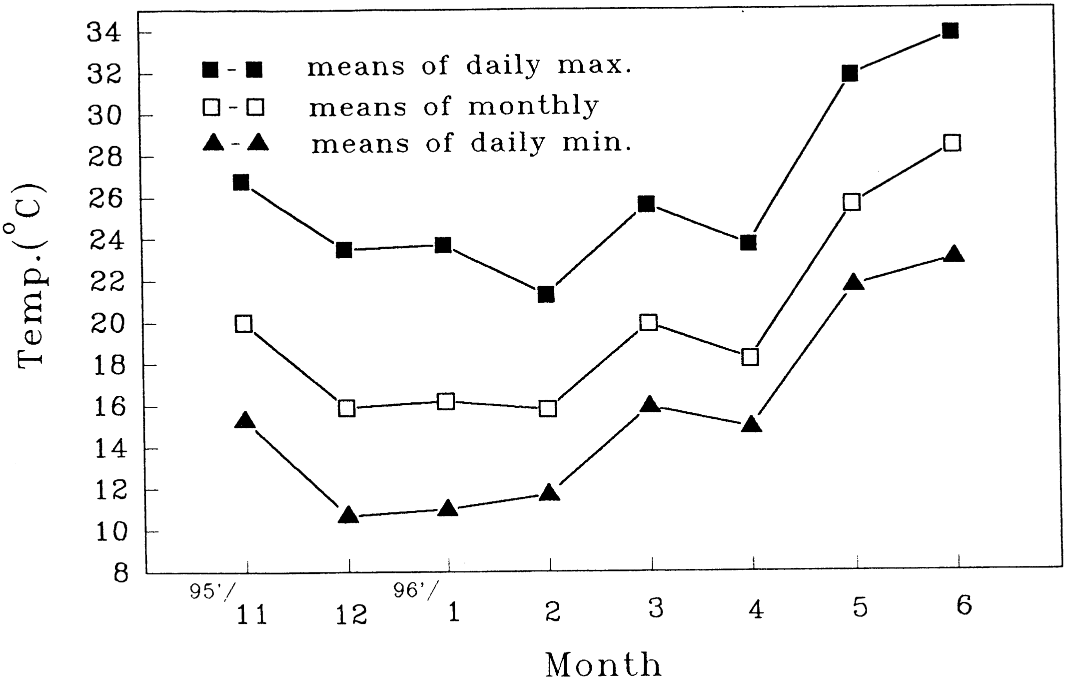

圖 1. 從桃開花前期至果實成熟期臺中地區每月最高、最低與平均溫度記錄

Fig. 1. The winter temperature record from pre-bloom to ripening period at Taichung, Taiwan

於 5 月中旬較早採收的品種有 '7669'、'7612'、'Premier'、及 'Flordagold'，果實發育日數爲83、91、96及98天爲早熟種，其發育所需熱量時間爲821、866、948及1,066°Cd；晚熟的品種有 '鶯歌桃' 及 '苦桃'，其發育所需日數及熱量時間，分別爲133和147天及1,523和1,581°Cd，其他爲中熟品種有 'Flordagold'、'Tropic Snow'、'Tropic Sweet'、'早生福州大桃' 及 'Okinawa'，其發育所需日數分別爲109、111、115、113、128天，發育所需熱量時間分別爲1022、1052、1194、1237、1264°Cd（表3.）。以 'Okinawa' 和 'Flordagold' 二品種爲例來比較，'Okinawa' 開花低溫需求爲 75CU，盛花期早在 1 月26日，而 'Flordagold' 其開花低溫需求爲 325CU，盛花期晚至 2 月23日，相差28天，二品種經濟採果期分別爲 6 月 1 日及 5 月30日僅相差一天，顯示早開花者，其果實不一定早熟；而 '7669' 和 'Flordagold' 盛花期均爲 2 月23日，二品種經濟採果期（'7669' 爲 5 月15日）卻相差15天，並不因同時間開花而有相同的採果期；故桃的成熟時間是分別依開花時期與果實發育日數的長短決定，而果實發育日數則是依品種特性而異，此和1986年 Munoz 等人[13]結論相同。

表 3. 桃不同栽培種果實發育所需日數及熱量時間，霧峰：1996.

Table 3. Investigation on FDP and thermal time of peach, Wu-Feng, 1996.

Cultivar	Full bloom date	Harvest date	FDP[z] (days)	Thermal time (°Cd)	Ripening rate[y]
7669	2/23	4/27～5/22	83	821	E
7612	2/15	4/30～5/22	91	866	E
Premier	2/15	4/30～5/30	96	948	E
Flordagold	2/23	5/11～5/30	98	1,066	E
Flordared	2/2	5/ 4～5/30	109	1,022	M
TropicSnow	2/2	5/10～6/ 1	111	1,052	M
TropicSweet	2/8	5/22～6/ 6	115	1,194	M
Tzao-sheng-fu-jou-dah-taur (早生福州大桃)	2/15	5/30～6/13	113	1,237	M
Okinawa	1/26	5/28～6/10	128	1,264	M
In-ge-taur (鶯歌桃)	2/2	6/ 6～6/28	133	1,523	L
Kuu-taur (苦桃)	2/15	7/ 5～7/19	147	1,581	L

z Fruit development period from full bloom (60～80% flowers open) to first commercial harvest.
y E : early (FDP 71～99 day); M: moderate (FDP 100～130 day); L: late (FDP>130 day)[1].

由美國引入 ‘Flordagold’ 、‘TropicSnow’ 、‘TropicSweet’ 和 ‘Flordagold’ 等四栽培種爲例，和原產國調查比較，相同種類品種生長在佛羅里達州 Gainesveille 果實發育日數分別爲95天[14]、97天[17]、100天[15]和88天[20,22]，而在臺灣霧峰本所則分別爲109天、111天、115天和98天，果實發育日數約10至15天。此顯然是臺灣花期較早，果實發育初期氣候較爲冷涼，果實發育所需熱量時間較慢滿足，故果實發育所需的日數拉長緣故。此結果和 Rouse[16] 在1989年的報告相同，其指出生長在德州 Rio Grande Valley 的果實發育日數比生長在佛羅里達州 Gainesville 的的果實發育日數平均早 5 至10天[14,15,17]，此由於從開花到採收期間日平均氣候溫度較溫暖所致。Sherman 等人[20] 1984年也相當淸楚的指出，果實發育日數是隨著果實發育期間氣溫而變動，氣溫低者比氣溫高者果實發育日數較長；在冷春及高冷地區由於在果實發育期間氣溫較暖春及低海拔地區爲低，因此果實較晚成熟。

雖然桃可用盛花後生育日數及利用儀器檢查糖酸度來預估果實成熟期，但採收上仍以觀察果形大小、果皮色澤、嗅聞其香氣、感觸其硬度，判斷其熟度爲方便省事。但採收時依銷售市場遠近，可分爲硬熟期、適熟期與軟熟期三個階段[2]，故果實採收日數因品種、種植地區、氣候、成熟度要求而會有所差異。

綜合上述，桃的成熟時間是依開花時期與果實發育日數的長短而定。開花時期是受每一栽培種的低溫需求量所調節，以及低溫滿足後的積溫而定。果實發育日數則依品種而異，受每一品種從盛花期至成熟的熱量累積值所調節。而由各品種果實發育所需的日數長短和滿足熱量時間的快慢，可預測果實成熟期的早晚。此在蘋果、梨、櫻桃、桃方面研究亦有相同看法[8,9,10]。因此參考桃栽培種開花所需的低溫需求量及配合果實發育所需的日數和熱量時間，可做爲地區選擇早晚熟桃栽培種的依據。

誌 謝

承蒙農委會多年來對「低需冷量桃品種改良」的經費補助，本所種原室溫英杰博士1980年代所建立的桃品種園，謝素玉、劉麗玉及陳美雪等計畫助理協助田間調查工作，陳耿信先生協助果園栽培管理工作，謹致謝忱。

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Thermal Time Required for Fruit Development in Low－chill Peaches[1]

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Summary

Thermal time (degree days needed from full bloom to commercial harvest on a 10°C baes temperature) and fruit development period (FDP) of 11 low－chill peach cultivars were calculated at Wu－feng (elevation 85m) in central Taiwan, 1995－1996. Ripening time of peaches depended on time of full bloom and length of the FDP. It revealed that peach culitivars could be classified into 3 types by different FDP and thermal time, i.e. early repening (FDP 83－98 days, thermal time, 821－1,066°Cd), moderate ripening (FDP 109－ 128 days, thermal time, 1022－1264°Cd) and late ripening (FDP>130 days, thermal time> 1523 °Cd) .

Key words : Peach, Low－Chilling requirement, Fruit development period, Thermal time, Ripening date.

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不同樹種來源單獨與混合木屑對杏鮑菇瓶栽生產影響之研究[1]

彭　金　騰[2]

摘要：本研究係以金針菇瓶栽自動化設備進行不同樹種來源單獨及混合木屑對杏鮑菇自動化瓶栽生產影響之測定。第一期試驗以堆積過 4 個月之杉木與楓木木屑爲原料，經添加20％體積之米糠及適量之碳酸鈣與水，均勻混合後，以自動化裝瓶機裝瓶（1,100ml），每瓶基質約重650公克，含水量約65％，經於20～22°C分別培養42及40天後，以人工去皮栽培，採收兩週期之每瓶產量，前者爲71.8公克，後者爲149.5公克，差異顯著。同期試驗中，另以楓木木屑基質做去皮與不去皮處理，採收兩周期之每瓶平均產量分別爲128與124.3公克，無顯著差異。第二期試驗以堆積過 5 個月之校櫕、杉木、楓木、相思木、山黃麻及楠木等六樹種單種木屑，如第一期配方製作基質及裝瓶，經接種培養43天後，不開蓋不去皮，待降溫至出菇時開蓋，經栽培後，以上各樹種木屑第一周期每瓶平均產量依序爲117.7，95.6，134.8，110.8，150.1及142.0公克，完成第一周期菇之採收分別需要10.0，11.9，6.7，8.6，5.1及6.1天，兩周期之產量依序爲169.3，157.9，207.1，172.0，219.6及214.7公克。其中山黃麻，楓木及楠木三樹種木屑間之兩周期平均產量無顯著差異，而相思木、杉木及校櫕三樹種木屑間亦同，但前三者之平均產量顯著高於後三者。第三期之試驗以堆積過 7 個月之杉木木屑分別與堆積相同時間之山黃麻、楠木、相思木、楓木、臺灣赤楊及校櫕木屑各半混合，並添加前述相同體積比之米糠時，以山黃麻單種木屑爲對照，經接種培養33天後，不開蓋不去皮，待降溫至出菇時開蓋，以上各樹種木屑與杉木木屑之混合物第一周期每瓶（1,100cc）之平均產量依序爲141.9，112.6，117.6，150.9，151.2及115.4公克，而對照爲148.2公克，第一周期菇完成採收分別需要14.0，16.7，17.2，11.0，12.5及13.8天，對照爲11.7天，兩周期之產量依序爲202.4，172.5，175.6，212.9，205.2及167.9，對照爲204.9公克，杉木木屑與山黃麻，楓木及臺灣赤楊三樹種木屑各半混合處理間之第一周期及兩周期之平均產量均無顯著差異，而與相思木、校櫕及楠木三樹種木屑各半混合處理間之平均產量亦無顯著差異，但杉木木屑與前三樹種木屑之混合處理之平均產量顯著高於後三樹種木屑之混合處理，山黃麻木屑與杉木木屑混合後之產量與該樹種單種木屑間無顯著之差異，但其第一周期菇完成採收之時間則有顯著延遲之現象。

關鍵詞：杏鮑菇、木屑、樹種、瓶栽生產。

杏鮑菇〔*Pleurotus eryngii*（DC.：Fr.）Quêl.〕是高品質之食用菇[3,5,7]，雖然可用麥桿或稻草栽培，但其菌絲對其他雜菌之抵抗力弱，出菇期間因基質與外界接觸面大，極易受雜菌，特別是木黴之感染，而導致栽培失敗[1,6,8]。若以木屑塑包栽培時，其基質裝入塑膠袋中，經高溫或低溫殺菌，雖

1. 臺灣省農業試驗所　研究報告第1885號。
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可減少雜菌感染，出菇時若僅拔除頸環之棉花塞，使之在頸口出菇，可產生較高品質之菇體，但受限於出菇面積，產量較低，若於木屑塑膠包底部或包身做十字割口，雖可形成較多菇體，且產量較高，但菇體品質較差[2]。此外以木屑塑膠包栽培時，太空包之製作及接種無法自動化，栽培後廢太空包較難處理，每包重達1.2～1.4公斤，搬運時較爲笨重而耗費體力，在農村勞力缺乏，僱工困難之下，恐不利於將來杏鮑菇之商業化栽培[2]。又杏鮑菇之生長發育適溫爲15～19°C，超過20°C時菇體容易死亡，如欲利用低溫之自然氣候下栽培，產量勢必無法穩定，且一年中可栽培季節甚短，恐不利於該產業之發展，惟如果利用金針菇之塑膠瓶在空調條件下栽培，則栽培材料之混合，裝瓶及接種可完全自動化節省勞力，而塑膠瓶可重複使用十年以上，大爲降低生產成本，栽培廢料清除容易，經適當處理可做爲有機肥料，不致破壞環保。此外，在空調條件下栽培，產量穩定，可視市場需要決定生產量，價格較爲平穩，且所需溫度較金針菇爲高，可降低能源成本，一舉數得，是非常值得開發之杏鮑菇生產技術。杉木【*Cunningahmia lanceolata* (Lamb.) Hook. var. *lanceolata*】爲金針菇業者使用最廣泛之木屑樹種，其木屑量多且較任何其他樹種木屑價廉，相思樹【*Acacia confusa* Merr.】則爲香菇菇農使用最普遍之樹種，來源不虞匱乏，楓木【*Liquidamber formosana* Hance】，臺灣赤楊【*Alnus formosana* (Burkill) Makino】及校欑【*Cyclobalanopsis glauca* (Thumb.) Orest.】也是香菇業者採用之樹種，其木屑來源較少，價格較相思樹木屑爲高，山黃麻【*Trema orientalis* (Linn.) Bume】及楠木【*Machilus kusanoi* Hay】則爲木耳及鮑魚菇類菇農使用較多之樹種，其木屑較香菇栽培所使用之樹種木屑便宜，由於不同菇類對其基質成份有不同之要求，其對基質之分解能力，亦有所不同，以上各樹種之木屑何者最爲適合杏鮑菇自動化瓶栽及其等與較便宜之杉木木屑混合後，對杏鮑菇生產之影響爲本研究探討之主題。

材料與方法

一、供試杏鮑菇品系：所使用之杏鮑菇品系爲美國引進的 ATCC 36047（美國菌種保存中心鍾順昌博士贈送）。以馬鈴薯葡萄糖洋菜培養基做定期培養，並以液氮做長久保存。

二、小麥菌種之製作：本試驗供木屑原種接種之小麥菌種以下法製作，小麥先以水洗淨並以冷水煮至沸騰，保持約20分鐘，濾除水分後，隨即填加２％碳酸鈣與１％之石膏，冷卻後裝入四角瓶，塞好棉塞以高壓蒸氣殺菌（121°C，１小時），隔夜冷卻後以上述杏鮑菇品系培養於 PDA 之菌絲塊接種，定溫培養於25°C約15天，當菌絲長滿小麥後即得小麥菌種。

三、供試木屑原種之製作：供自動化接種機大量接種所使用之原種採用山黃麻木屑爲原料，以添加木屑體積四分之一之米糠及每0.5立方公尺之木屑加1.5公斤之碳酸鈣混合加水後，以本方法第(五)項之栽培材料裝瓶殺菌，並採用小麥菌種接種，經培養於24°C一個月而成。

四、栽培材料及配方：栽培主要材料之木屑，其來源樹種包括山黃麻，杉木，楓木，臺灣赤楊，校欑，相思木及楠木等。米糠爲未脫脂之蓬來米米糠，所有不同樹種單獨或混合木屑與米糠體積比均爲４：１，每0.5立方公尺之木屑，添加1.5公斤碳酸鈣與40公斤之米糠，所使用之木屑來源樹種，第一期栽培試驗爲杉木與楓木，第二期栽培試驗爲校欑，杉木，楓木，相思木，山黃麻及楠木，第三期栽培試驗爲杉木，山黃麻，相思木，楓木，臺灣赤楊，校欑及楠木。第一期與第二期試驗爲不同單樹種木屑間之比較，第三期栽培試驗爲杉木與其他樹種木屑各半混合間之比較，以山黃麻木屑爲對照。以上各樹種木屑均爲鋸木廠之木屑，非人工打碎者，其顆粒較後者爲細，使用前均經電動篩選機（孔口大小爲１平方公分）篩選，以除去混雜之木塊、木片及其他雜物等。這些木屑依試驗期別依序堆積４，５及７個月，除第一個月爲加水翻堆外，其後每隔一個月視需要加水翻堆一次。

五、栽培材料之裝瓶、殺菌及接種：以上各配方之材料利用自動混合機混合，並以自動計量設備調節

混合物含水量於約65%後，以輸送帶輸送至自動裝瓶機（協全 KPAC-50-2），經自動裝填，壓緊，打洞，封蓋（每次12瓶，每瓶1,100ml，基質每瓶重約650公克）後，以輸送帶移入具有電腦自動化控制殺菌程式之殺菌釜（廣太源）殺菌（瓶中心溫度達122°C時保持45分鐘）。殺菌完成後移入冷卻室冷卻，隔夜後輸入無菌接種室，以自動化接種機（協全 RS-2000型）接種，所用之原種為 PP 塑膠瓶裝之山黃麻木屑菌種。

六、栽培菌種之培養與出菇採收：栽培用菌種經接種後輸入菌種培養室，溫度設定於20至22°C，相對溼度控制於75至85%，待菌絲長滿培養材料（約需23天）再保持10至18天後，開蓋檢查瓶內有無雜菌，選取無雜菌之栽培菌種瓶移入出菇室，以每框12瓶，依不同期次試驗，每重覆4至5框，採逢機排列法置於菇架上，菌種瓶暫不開蓋，並依試驗需要做去皮（挖除舊菌種）或不去皮處理。出菇室溫度設定於16.5至18.5°C，相對溼度利用超音波噴霧機控制於95%左右，二氧化碳濃度利用熱交換機輸入新鮮空氣控制於0.06%左右。此時不需光線，待瓶內形成小子實體後，打開瓶蓋並供應光源，光度控制於 250lux 左右，每日光照8小時，待菇體發育適當，菌傘邊緣尚未向上翻時，予以採收並秤重，記錄產量。

結果與討論

在第一期栽培試驗裡，進行杉木與楓木兩種樹種木屑之比較，有去皮之情形下，每瓶採收兩周期之平均產量分別為71.8與149.5公克（表1），兩樹種木屑間有顯著之差異，杉木木屑出菇較不整齊且慢，可能因為含有精油，阻礙杏鮑菇菌絲之營養吸收與生長所致。另以楓木木屑為材料做去皮與不去皮之比較，去皮與未去皮每瓶兩周期之平均產量分別為128.0與124.3公克，並無顯著之差異（表2）。

表 1. 以杉木與楓木木屑為基質原料瓶栽杏鮑菇之產量比較

Table 1. Comparison of the productivity of bottle cultivation of the *Pleurotus eryngii* strain ATCC 36047 on two sawdust substrates of *Cunninghamia lanceolata* var. *lanceolata* and *Liquidamber formosana*[z]

Sources of sawdust	Yield (g/60bottles)						Average[y]
	1	2	3	4	5	6	
C. lanceolata	4,200	4,180	4,160	4,440	4,340	4,530	4,308.3 b (71.8)[x]
L. formosana	8,800	8,030	9,430	9,410	8,930	9,220	8,970.0 a (149.5)[x]

[z] Sawdusts and rice bran were mixed in a ratio of 4 : 1 by volume. The mixed sawdusts were heaped for 4 months. Filling and inoculation of substrate were conducted by automatic machines. Each substrate had 6 replicates. Each replicate consisted of 60 1,100ml bottles. Each bottle contained about 650g of substrate (wet) of which moisture content was about 65%. Inoculated substrates were incubated at 20~22°C for 42 days. Top layers (*C. lanceolata*) or 40 days (*L. formosana*). Top layers (ca 1.5cm in depth) of substrates in bottles were removed by hand after cropping room had been cooled down to 16.5~18.5°C for three days. The cropping room was maintained at 16.5~18.5°C in temperature, about 95% in RH, 250 lux in light intensity during cropping. Harvesting period was 28 days for *C. lanceolata* and 32 days for *L. formosana*.

[y] Means with the same letter of a column are not significantly different at 5% level by Duncan's multiple Vauge Vange test.

[x] Means in brackets are the average yield in each bottle (g/bottle).

表 2. 瓶口處理對杏鮑菇菌株 ATCC 36047產量之影響

Table 2. The effect of top layer treatment on the yield of the *Pleurotus eryngii* strain ATCC 36047[z].

Top layer treatment	Yidld (g/60 bottles)				Average[y]
	1	2	3	4	
removed	7,400	8,050	7,320	7,950	7,680.0 a (128.0)[x]
not removed	6,670	7,380	7,380	8,400	7,457.5 a (124.3)[x]

[z] Sawdusts of *L. formosana* and rice bran were mixed in a ratio of 4 : 1 by volume The sawdusts were heaped for 4 months. Filling and inoculation of substrate were conducted by automatic machines. Each treatment had 4 replicates. Each replicate consisted of 60 1,100ml bottles. Each bottle contained about 650g of substrate (wet) of which moisture content was about 65%. Inoculated substrates were incubated at 20～22°C for 42 days. Top layers (ca 1.5cm in depth) of substrates in bottles in the " removed" treatment were removed by hand after cropping room had been cooled down to 16.5～18.5°C for three days. The cropping room was maintained at the same climatic conditions as those in Table 1. Harvesting period was 32days.

[y] Means with the same letter of a column are not significantly different at 5% level by Duncan's multiple range test.

[x] Means in brackets are the average yield in each bottle (g/bottle) .

第二期栽培試驗爲校欖，杉木，楓木，相思木，山黃麻及楠木等六樹種木屑之比較，在未去皮處理下，第一周期每瓶平均產量依序爲117.7，95.6，134.8，110.8，150.1及142.0公克，以山黃麻之產量最高，次爲楠木與楓木，再次爲屬於硬木類之相思木與校欖，屬於針葉木之杉木最差（表 3）。山黃麻與楠木兩樹種之木屑出菇快而整齊，第一周期菇 5 至 6 天內即可採收完成，次爲楓木平均須6.7天，而相思木則須8.6天，杉木與校欖更須10至12天之久（表 3）。第二周期之採收量，以上六種木屑每瓶平均產量依序爲51.6，61.9，72.2，61.2，70.1及72.6公克，其中相思木，校欖及杉木之產量較差（表 3）。以上兩周期之平均產量，上述樹種依序爲169.3，157.9，207.1，172.0，219.6及214.7公克，其中山黃麻，楓木及楠木三樹種木屑間之平均產量並無顯著之差異，而相思木，杉木及校欖三樹種木屑間亦同，但前三種木屑較後三種木屑產量高且有顯著之差異（表 3）。屬於硬木類之相思木及校欖木屑，可能杏鮑菇菌絲分解不容易，導致產量較低，而杉木則可能因爲含有精油有礙杏鮑菇菌絲之營養吸收與生長，以致出菇較慢且不整齊。至於降溫至開始採收所需之平均天數，不同樹種間僅有些微差異（表 3），但平均產量較低之樹種所需之天數未必較多。第二期試驗之杉木及楓木木屑每瓶平均產量顯然高於第一期試驗（表 1），似與刺激出菇方式有關，第一期試驗時，有做去皮處理，即挖除舊菌種或以小鐵匙刮除瓶口木屑表面之大部份菌絲層，然後不蓋回瓶蓋，以噴霧機增加空氣中之溼度促進瓶口木屑表面菌絲再生，惟由於溼度增加似不夠均勻，且不易維持均勻而固定之溼度，以致菌絲再生無法一致，出菇慢而且不整齊，部份栽培用菌種瓶可能僅出菇一次，採收即已結束，因此產量較低。由於第一期試驗時，部份未列入試驗用之楓木木屑栽培用菌種，於降溫後未做去皮處理，也未開瓶蓋，經降溫後 7 至10天時開蓋，偶然發現絕大部份之菌種瓶內均有小菇形成，經開蓋後，菇體發育整齊，第一周期每瓶產量約可達150公克。因此本期試驗時，於降溫後未立即開蓋，也未做去皮處理，待降溫後 7 天開始開蓋檢查有無小菇形成，沒有則蓋回瓶蓋，往後隔日檢查至完全出菇取下所有瓶蓋爲止。第一周期菇採收結束後當日蓋回瓶蓋以促進瓶口菌種表面菌絲再生以利出菇，約 6 至 8 天即可再形成小菇體。由於兩周期出菇均相當整齊，因此本期試驗無論杉木或楓木木屑之產量均顯著高於第一期試驗。未開蓋有利杏鮑菇出菇，除了瓶內溼度高且較易保持之外，二氧化碳濃度較高可能也是因素之一，杏鮑菇菇蕾之正常發育需要有光線與低濃度之二氧化碳[4,8]，但由營養菌絲集結形成菇蕾，依本試驗觀察是不需要光線或只需極微弱之光線，而且在高濃度二氧化碳下進行，此結論與

Cailleux & Diop 兩氏[4]之試驗結果相符合，即杏鮑菇菇蕾在二氧化碳濃度爲1,000～1,500ppm 下可形成，但由菇蕾發育爲正常之子實體，則二氧化碳之濃度須在800ppm 之下。因此在商業經營上，杏鮑菇之生產若採用僅收獲一次之方式，爲節約能源消耗，栽培用菌種培養結束後似可直接降溫至產生菇蕾時，方移至出菇室並提供適量光線與適量之二氧化碳濃度，使菇體發育至吾人所期望之形態，以節省栽培用菌種佔用出菇室之時間，提高出菇室利用效率，降低生產成本。此外在栽培過程中也發現，杏鮑菇之菇蕾甚少形成於舊菌種（即母種）之上，因此若栽培用菌種之舊菌種佔滿瓶口時，有出菇嚴重延遲現象，而菇蕾絕大部份形成於未被原種覆蓋之瓶口表面濃密菌絲層上。因此杏鮑菇栽培用菌種製作時，如不欲去皮而使菇蕾直接形成於瓶口菌絲表面時，菌種量不宜太多以致佔滿瓶口，延遲出菇。

第三期栽培試驗爲杉木木屑分別與山黃麻，楠木，相思木，楓木，臺灣赤楊及校鑽等之六樹種木屑各半混合之產量比較，以山黃麻單樹種木屑爲對照。第一周期之每瓶平均產量以上六樹種木屑依序爲141.9，112.6，117.6，150.9，151.2及115.4公克，對照爲148.2公克，杉木木屑與山黃麻，楓木及臺灣赤楊三樹種木屑各半混合處理間之平均產量無顯著差異，而與相思木，校欑及楠木三樹種木屑各半混合處理間之平均產量亦無顯著之差異，但杉木與前三樹種各半混合處理之平均產量均較其與後三樹種各半混合處理之平均產量爲高且有顯著之差異（表４）。第二周期之每瓶平均產量上述六種樹種混合木屑，依序爲60.5，59.9，57.9，61.9，54.0及53.2公克，對照爲56.7公克，杉木木屑與該六樹種木屑各半混合處理間之平均產量並無顯著之差異（表４）。兩周期之每瓶平均產量上述六種樹種混合木屑依序爲202.4，172.5，175.6，212.9，205.2及167.9公克，對照爲204.9公克，兩周期之每瓶平均產量，杉木木屑與六樹種木屑各半混合處理間之比較結果與第一周期之每瓶平均產量相同（表４）。降溫至第一周期菇開始採收所需時間，除與相思木木屑混合之處理較長外，杉木木屑與其他樹種木屑混合處理間並無顯著之差異（表４），此與各樹種單種木屑爲材料時略有不同，因此添加杉木木屑似有降低不同樹種木屑間差異之效果。山黃麻木屑無論有否與杉木木屑混合，其降溫至第一周期菇開始採收所需時間均相同（表４）。杉木木屑與其他樹種木屑混合處理間，其第一周期菇採收完成所需時間有顯著之差異（表４），其中杉木木屑與山黃麻、楓木、臺灣赤楊及校欑各樹種木屑之混合處理較與楠木及相思木之混合處理爲短，其差異達５％顯著水準。杉木木屑與楓木木屑之混合處理，其第一周期菇完成採收所需時間最短，但若與杉木木屑與臺灣赤楊之混合處理或山黃麻單樹種木屑比較，則無顯著之差異（表４）。山黃麻木屑與杉木木屑混合後，其第一周期菇完成採收所需時間延長且達５％之顯著水準。由表４結果顯示，山黃麻木屑與杉木木屑混合後，其第一周期及兩周期菇之產量略減，但未達５％之顯著水準，因爲杉木木屑較其他木屑便宜甚多，可直接降低杏鮑菇之生產成本，惟會延長第一周期菇採收完成所需時間，若栽培經營上採用只採收一次之作業，類似金針菇之栽培時，可能會增加能源消耗，在經濟上之效益尙待進一步重複試驗後評估。

本試驗研究結果顯示，栽培杏鮑菇所使用之木屑樹種，以屬於軟木闊葉樹種，如山黃麻，楠木，楓木及臺灣赤楊最適合，屬於硬木類闊葉樹種，如相思木，校鑽則比較差，屬於針葉樹種的杉木，雖然亦可使用，但產量較差且出菇慢而不整齊，不過後者之木屑若與山黃麻或楓木木屑等量混合，則產量與後兩樹種木屑單獨使用並無顯著之差異，可做爲日後栽培杏鮑菇之參考，因此杉木木屑通常較闊葉樹木屑便宜，可顯著降低生產成本，惟兩種木屑應以何種比例混合最具經濟價值，則尙待進一步之研究。此外屬於軟木類之楠木木屑與杉木木屑混合後，其產量顯然較單樹種木屑（表３）爲低，且與杉木木屑和其他硬木類之木屑，如相思木或校欑木屑之混合處理無顯著之差異（表４），而完成第一周期菇之採收也顯然延長，此是否因爲楠木木屑不耐長期堆積，容易分解，導致不利杏鮑菇生長發育之物理或化學變化而使產量降低，其原因有待進一步探討。

表 3. 不同來源樹種木屑對杏鮑菇瓶栽生產之影響

Table 3. Effects of the sources of sawdusts on the production of the *Pleurotus eryngii* strain ATCC 36047 using bottle cultivation technology[z].

Sources of sawdusts	Average Yidld (g/bottle) [y]			Interval between 1st picking and starting cooling[y]	Days for finishing the harvest of 1st flush mushrooms[y]
	1st flush	2nd flush	1+2 flush		
Cyclobalanopsis glauca	117.7 c	51.6 c	169.3 b	17.0 days ab	10.0 b
Cunninghamia lanceolata	95.6 d	61.9 b	157.5 b	17.3 days a	11.9 a
Liquidamber formosana	134.8 b	72.2 a	207.1 a	16.6 days b	6.7 c
Acacia confusa	110.8 c	61.2 b	172.0 b	16.6 days b	8.6 b
Trema orientalis	150.1 a	70.1 ab	219.6 a	16.7 days ab	5.1 c
Machilus kusanoi	142.0 ab	72.6 a	214.7 a	17.0 days ab	6.1 c

[z] Sawdusts of different sources and rice bran were mixed in a ratio of 4 : 1 by volume. All sawdusts were heaped for 5 months before use. Filling and inoculation of the substrates thus prepared were conducted by automatic machines. Each substrate had 7 replicates and each replicate consisted of 36~48 bottles. Each bottle contained about 650g of substrate of which moisture content was about 65%. Inoculated substrates were incubated at 20~22°C for 43 days. Top layers of substrates in bottles were not removed and caps were not removed until primordia or young fruit bodies had been formed. The cropping room was maintained at about 95% in RH, 16.5~18.5°C in temperature and 250lux in light intersity (8 hours per day) .

[y] Means with the same letter of a column are not significantly different at 5% level by Duncan's multiple range test.

表 4. 杉木木屑與其他六種樹種木屑混合對杏鮑菇瓶栽生產之影響

Table 4. Effects of mixing the sawdusts of *Cunninghamia lanceolata* with those of other six species of trees on the production of the *Pleurotus eryngii* strain ATCC 3607 using bottle cultivation technology[z].

Combination of sources of sawdusts	Average Yidld (g/bottle) [y]			Interval between 1st picking and starting cooling[y]	Days for finishing the harvest of 1st flush mmushrooms[y]
	1st flush	2nd flush	1+2 flush		
C. lanceolata+*T. orientalis*	142 a	61 a	202 a	16.0 b	14.0 b
C. lanceolata+*M. kusanoi*	113 b	60 a	173 b	16.2 b	16.7 a
C. lanceolata+*A. confusa*	118 b	58 a	176 b	16.7 a	17.2 a
C. lanceolata+*L. formosana*	151 a	62 a	213 a	16.0 b	11.0 c
C. lanceolata+*Alnus formosana*	151 a	54 a	205 a	16.0 b	12.5 bc
C. lanceolata+*C. glauca*	115 b	53 a	168 b	16.2 b	13.8 b
T. orientalis (as control)	148 a	57 a	205 a	16.0 b	11.7 c

[z] The sawdust of *C. lanceolata* was mixed with equal volume of those of other six tree species respectively. Each mixture thus resulted and the sawdust of *T. orientalis* were mixed with rice bran in a ratio of 4 : 1 by volume respectively. All the sawdusts were heaped for 7 months before use. Filling and inoculation of substrates thus prepared were conducted by automatic machines. Each substrate had 6 replicates and each replicate consisted of 48 bottles and each bottle contained about 650g of substrate of which moisture content was about 65%. Inoculated substrates were incubated at 20~22 °C for 33 days. Top layers of substrates in bottles were not removed and caps were not removed until primordia or young fruit bodies had been formed. The cropping room was maintained at about 95% in RH, 16.5~18.5°C in temperature and 250lux in light intensity (8 hours per day) .

[y] Means with the same letter of a column are not significantly different at 5% level by Duncan's multiple range test.

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Study on the Effects of Single and Mixed Sawdusts of Different Origins on the Production of *Pleurotus eryngii*[1]

Jin-Torng Peng[2]

Summary

Study on the effects of single and mixed sawdusts of different origins on the production of *Pleurotus eryngii* was conducted using the automatic bottle cultivation technology for *Flammulina velutipes*. Sawdusts of differet origins, including *Cyclobalanopsis glauca, Cunninghamia lanceolate* var. *lanceolata, Liquidamber formosana, Acacia confusa, Trema orientalis* and *Machilus kusanoi,* were heaped for 5 months and mixed respectively with 20 % of rice bran (by volume) and proper amount of calcium carbonate and water. The substrates thus prepared were filled into polypropane bottles (1,100 CC) and capped with automatic machines, then sterilized at 122°C for 45 minutes in a programmable autoclave. Each bottle contained about 650g of substrate of which moisture content was about 65%. After cooling down the substrates were inoculated with sawdust spawn of the fungus by an automatic inoculating machine. The inoculated substrates were incubated at 18~21.5°C for 43days before moving into cropping room. Top layers of substrates in bottles were not removed and caps were not removed until primordia or young fruit bodies had been formed after cooling down of the cropping room. The cropping room was maintained at about 95 % in RH, 16.5~18.5°C in temperature and 250lux in light intensity. After cultivation the average total yields per bottle of the substrates consisted of the sawdusts of the above mentioned tree species were 169.3, 157.9, 207.1, 172.0, 219.6 and 214.7g in order, while the time for finishing the harvest of the lst fresh mushrooms were 10.0, 11.9, 6.7, 8.6, 5.1 and 6.1 days in order.The differences of yields among the substrates consisted of the sawdusts from *T. orientalis, M. kusanoi* and *L. formosana* were not significant at 5% level, while those of yields among the substrates consisted of the sawdusts from *C. glauca, C. lanceolata,* and *A. confusa* were not significant at 5% level either. However, the substrate consisted of the sawdusts from the former three tree species were significantly more productive than those consisted of the sawdusts from the latter three tree species at 5% level.

In another experiment, the sawdust of *C. lanceolata* was mixed with equal volume of the sawdusts of *T. orientalis, M. kusanoi, A. confusa, L. formosana, A. formosana,* and *C. glauca* and supplemented with same amount of rice bran as mentioned above. The inoculated substrates were incubated for 33days and cropped under the same climatic conditions as mentioned above. The average total yields per bottle of the substrates consisted of the

sawdusts of *C. Lanceolata* and equal volume of the above mentioned tree species were 202.4, 172.5, 175.6, 212.9, 205.2 and 167.9g in order, while the time for finishing the harvest of lst fresh mushrooms were 14.0, 16.7, 17.2, 11.0, 12.5 and 13.8days respectively. The average yield per bottle of the substrate consisted of the sawdusts of *T. orientalis* alone was 204.9g, while the time for finishing the harvest of the lst flush mushrooms was 11.7 days. The differences of the yields among the substrates consisted of the sawdust of *C. lanceolata* and equal volume of those from *T. orientalis, L. formosana* and *A. formosana* were not significant at 5% level, while the differences of the yields among the substrates consisted of the sawdust of *C. lanceolata* and equal volume of those from *C. glauca, M. kusanoi,* and *A. confusa* were not significant at 5% level either. However, the former three substrates were significantly more productive than the latter three ones at 5% level. The average yield of the substrate consisted equal volume of the sawdusts from *C. lancelata* and *T. orientalis* was not significantly different from that of the substrate consisted of the sawdust of the latter tree species alone, however, finishing the harvest of lst flush mushrooms of the former substrate took more days than the former one and was significantly different at 5% level.

Key words : *Pleurotus eryngii,* Sawdust, Tree species, Bottle cultivation.

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廢棄菇類木屑堆肥應用於洋香瓜育苗介質之評估[1]

張明暉　向為民　簡宣裕　黃維廷[2]

摘要：本研究以廢棄木耳、鮑魚菇木屑堆肥及本所堆積腐熟之廢棄金針菇木屑堆肥為洋香瓜育苗介質，根據其理化性，評估其應用於洋香瓜育苗介質之可行性；另以廢棄金針菇木屑堆肥及粉碎稻殼為主材料，調配不同混合比例之洋香瓜育苗介質，並同進口培養土於春、秋作進行育苗，比較瓜苗乾物重之差異。除此，並調查秋作瓜苗定植後植株之生育情形。本研究所得結果顯示如下：

1. 廢棄木耳、鮑魚菇木屑堆肥經添加展濕劑及肥力調整之後，雖可用作洋香瓜育苗介質，但其極有效水分含量偏低、灌溉次數須較頻繁，又其質地細緻，遇水後黏著，再濕性不良，即乾掉後收縮不易復原，管理不易，實非理想介質；而廢棄金針菇木屑堆肥保水力略低但通氣性良好，又其水溶性銨態氮、磷、鉀、鎂含量豐富；惟電導度甚高（EC＝5.4ds/m；介質：水＝1：5（w/w）），水溶性鈣含量遠低於進口培養土，而該瓜苗葉片分析，鈣含量亦較以進口培養土育苗者低；幼苗期新葉時而出現缺鐵黃化變小現象。經肥力調整後，可適用於洋香瓜育苗。
2. 廢棄金針菇木屑堆肥添加20％或40％粉碎稻殼；此介質1公升，混以5克碳酸鈣及5克硫酸亞鐵，瓜苗乾物重均較以純廢棄金針菇木屑堆肥育苗者增加，達5％顯著差異水準，可與以進口培養土育苗者相較，且秋作瓜苗定植後，植株明顯比以進口培養土育苗者健壯。

關鍵詞：廢棄菇類木屑堆肥、洋香瓜育苗介質、介質理化性質。

根據臺灣農業年報統計，近年來臺灣每年蔬菜栽培面積約20萬公頃左右，其中約4萬7千公頃蔬菜須經移植栽培，即須先經育苗，再於定植栽培，諸如：蕃茄、甜椒、甘藍、花椰菜、結球白菜以及瓜類等，可知臺灣蔬菜每年育苗數量相當可觀，由於勞力不足，傳統苗圃育苗方式，費時費工，發芽不一，移植時根系易受傷感染，延後生長期；近年來穴盤育苗技術引入，不但改善了傳統育苗方式之缺失，更促使蔬菜、花卉育苗機械化、自動化，達到企業化一貫要求。

近年來業者大多以進口栽培介質為其育苗資材，其用量相當可觀。而本省一年栽培香菇、木耳、鮑魚菇、金針菇廢棄鋸木屑量分別為54,000公噸、40,500公噸、2,250公噸、22,500公噸，合計119,250公噸；又根據臺灣省農業年報（1992年）統計，臺灣每年稻殼廢棄物高達50萬公噸，對於如此大宗之農業廢棄物，再生利用之即為資源。故近年國內外利用農業廢棄物為栽培介質之有關研究文獻很多[1,2,3,5,7,9]。

作物生長良窳，深受栽培介質之理化性質影響，而物理性質，尤以通氣性及保水性最為重要，蓋育苗用穴盤高度僅約6公分，盆底即如同地下水位，排水常為限制因子[10,11]，然又該容器體積小，水分及養分供應有限，故以保水性佳之介質為適宜[6]。本試驗目的乃在於根據廢棄木耳、鮑魚菇木屑堆

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肥與廢棄金針菇木屑堆肥之物理性、化學性，評估其作爲洋香瓜育苗介質之可行性；並以廢棄金針菇木屑堆肥、粉碎稻殼調配研發洋香瓜育苗介質，以開發本土化介質，增進農產廢棄物再生利用。

材料與方法

一、供試材料

㈠廢棄木耳、鮑魚菇木屑堆肥，JMWC, Jew's ear and oyster mushroom waste (sawdust) compost：取材自嘉義縣中埔鄉社口有機資源處理中心，其組成分爲廢棄木耳、鮑魚菇太空包添加雞糞、豆粕類、蚵殼粉混合製造之木屑堆肥。

㈡廢棄金針菇木屑堆肥，WMWC, winter mushroom waste (sawdust) compost：取材自臺中縣霧峰鄉戴養菌園，加入65%水分，於臺灣省農業試驗所堆肥場堆置，每週翻堆一次，經 3 個月腐熟而成。

㈢粉碎稻殼，milled rice hulls：由本省稻殼經粉碎所得，該粒徑分佈如表 1 所示。

㈣泥炭苔：丹麥FINNPEAT A2.

㈤進口培養土一：荷蘭 Florafleur 001J。

㈥進口培養土二：荷蘭 BVB 2.

㈦洋香瓜品種：秋香（農友種苗公司）。

表 1. 堆肥與粉碎稻殼之粒徑分佈

Table 1. Particle size distribution of composts and milled rice hulls.

U. S. Standard sieve number	Openings mm	Screen analysis JMWC	WMWC	milld rice hulls
		%, wt		
4	4.76	3.3	0.5	0.0
10	2.00	10.6	9.3	4.1
16	1.00	12.3	19.5	51.7
35	0.50	17.5	30.7	37.6
Pan	<0.50	56.3	40.0	6.6

二、方法

㈠育苗介質之物理性與化學性測定

1. 物理性測定

(1)粒徑分佈

廢棄木耳、鮑魚菇木屑堆肥和廢棄金針菇木屑堆肥及粉碎稻殼等供試材料，經70°C烘乾24小時之後，分別逢機取樣200ml，3 重複，倒入電磁篩選震盪器震盪10分鐘，然後計算存留於篩網粒徑4.76、2、1、0.5mm 及底盤上介質所佔之重量百分率，其粒徑分佈如表 1 所示。

(2)根據 DeBoodt & Verdonck[8]建立之標準化系統，測定廢棄菇類木屑堆肥、進口泥炭苔及進口育苗用培養土於水分張力 0、10、50cm 水柱狀況下之水分特性，5 重複，其測定方法如下：

總孔隙度（total porosity, TPS）：當介質於水分張力＝0 cm 之體積含水百分率。

充氣孔隙度（air space, AS）：介質於水分張力10cm 下之充氣孔隙百分率。

極有效水分（easily available water, EAW）：介質於水分張力10～50cm 範圍內之體

積含水百分率。

固相＝100－液相－氣相。

液相＝總孔隙度（TPS）－充氣孔隙度（AS）。

氣相＝介質之充氣孔隙度（AS）。

(3)總體密度

總體密度是以介質烘乾重與其總體積之比（g/cm^3）。

2. 化學性測定

(1)酸鹼度（pH）

以介質：水＝1：5（w/w）酸鹼度計測定。

(2)電導度（EC）

以介質：水＝1：5（w/w）電導度計測定。

(3)介質營養料分析

水溶性分析：以介質：水＝1：5（w/w），震盪 1 小時，過濾之，取濾液測定銨態氮、磷、鉀、鈣、鎂。銨態氮 以氨分析儀（ammonia analyzer），磷、鉀、鈣、鎂以 ICP 測定。

有效性分析：以介質：0.1M 酸鹽＝1：10（w/w），震盪 1 小時，過濾之，此濾液供鐵、錳、銅、鋅以 ICP 測定。

(二)不同育苗介質育洋香瓜苗之比較試驗

1. 木屑堆肥育洋香瓜苗觀察：

添加展濕劑（AquaGro 2000. L）於廢棄木耳、鮑魚菇木屑堆肥，每週澆氮、鉀養液 100ppm 兩次，完全逢機設計，3 重複，觀察洋香瓜（秋香）瓜苗生育情形。

2. 調配之育苗介質與進口培養土於洋香瓜育苗之比較試驗：

根據堆肥理化性質分析及觀察試驗中呈現之葉片養分缺乏症狀，並由葉片分析（濃酸分解法）資料，調整堆肥理化性質，將粉碎稻殼混入堆肥以降低成本，添加碳酸鈣以補充鈣素，添加硫酸亞鐵以改善瓜苗缺鐵現象。以堆肥、粉碎稻殼、碳酸鈣、硫酸亞鐵四種材料，不同比率、濃度混合，不完全組合設計，選得兩種最佳混合比率之介質配方，並同進口培養土，於春、秋兩作（春作：1996.4.25～1996.5.15；秋作：1996.9.4～1996.9.23）進行育苗比較試驗，以純廢棄金針菇木屑堆肥爲對照，處理如下表 2 ，完全逢機設計，春作 7 重複，秋作 8 重複。

表 2. 本研究育苗介質之處理

Table 2. Treatments of seed-sowing media.

介質	$CaCO_3$ (g/1L Media)	$FeSO_4$ (g/1L Media)
1. 廢棄金針菇木屑堆肥（WMWC）	0	0
2. 廢棄金針菇木屑堆肥＋20％粉碎稻殼（WMWC＋20％RH）	5	5
3. 廢棄金針菇木屑堆肥＋40％粉碎稻殼（WMWC＋40％RH）	5	5
4. 進口培養土一（Florafleur 001J）	0	0
5. 進口培養土二（BVB 2）	0	0

3. 瓜苗定植後植株之生育調查：

取前項試驗 2、3、4 三種處理於秋作所育得之瓜苗，進行定植後的生育比較試驗；追瓜苗本葉出出現 3 ～ 4 枚後，定植於1/2,000a Wagner's Pot 中，在溫室栽培，採完全逢機設計，5 重複；土壤爲砂質壤土，定植隔日點施臺肥43號複肥 5 克於每盆中。分別於定植後10天、15天、23天調查植株之生育特性。

結果與討論

一、廢棄菇類木屑堆肥洋香瓜育苗介質之評估

廢棄木耳、鮑魚菇木屑堆肥保水力爲69cm³/cm³，略低於進口培養土，充氣孔隙度則互有高低，如表 3 所示；該堆肥經添加展濕劑及肥力調整之後，雖可爲洋香瓜育苗介質育出健壯瓜苗，與業者慣用之進口培養土所育瓜苗乾物重比較，如表 4 所示。但其極有效水分含量偏低、灌溉次數須較頻繁，又其質地細緻，遇水後黏著，再濕性不良，即乾後收縮不易復原，管理不易，實非理想介質。

表 3. 不同介質之通氣及保水等物理性質比較

Table 3. Comparison of the physical properties of media regarding aeration and water retention.

Media	TPS[z]	EAW	Solid	Liquid	Gas[y]	Bulk density
	Volume %					g/cm³
JMWC	81.18	14.02	19	69	12	0.24
WMWC	76.46	24.66	23	60	17	0.18
FINNPEAT A2[x]	83.31	31.85	17	73	11	0.09
Florafleur 001J	89.03	21.42	11	69	20	0.14
BVB 2	88.03	34.60	12	76	12	0.13

[z] TPS: Total pore space defined at zero cm moisture tention.
EAW: Easy available water defined at the range of 10 and 50 cm moisture tension.
[y] The distribution of three phases at 10 cm moisture tention.
[x] FINNPEAT A2: Imported peat moss.
Florafleur 001J: Imported growing media 1.
BVB 2: Imported growing media 2.

表 4. 廢棄木耳、鮑魚菇木屑堆肥經展濕劑添加及肥力調整之後與進口培養土對洋香瓜瓜苗生產之影響

Table 4. Effect of the Jew's ear and oyster mushroom waste (sawdust) compost, with wetting agent added and fertility corrected, and the imported growing media on the growth of muskmelon seedlings.

Media	Shoot weight[x]	Root weight	Total dry weight
	mg/plant		
JMWC-WF[y]	536.67±30.55 b[z]	56.33±1.15 a	593.00±31.43 b
Florafleur 001J	670.00±43.59 a	39.33±8.08 b	709.33±48.84 a

[z] Means in each column followed by the same letters are not significantly different at 5% level (Duncan's Multiple Range Test).
[y] JMWC-WF: The JMWC with wetting agent added and culture solution (100ppm N、K) applied twice a week.
[x] Seedlings planted for 16 days in late June.

廢棄金針菇木屑堆肥保水力爲60cm^3/cm^3，略低但通氣性良好，如表 3 所示。又其水溶性銨態氮、磷、鉀、鎂含量豐富；惟該介質電導度甚高（EC＝5.4ds/m；介質：水＝1：5（w/w）），水溶性鈣含量遠低於進口培養土，如表 5 所示。該堆肥育成之瓜苗，葉片鈣含量亦較以進口培養土育苗者低，如表 6 所示。倪[1]分析廢棄金針菇木屑堆肥，亦曾發現可溶性鈣含量顯著低於廢棄金針菇木屑堆肥與泥炭苔混合者。以此堆肥爲介質培育瓜苗，新葉時而出現缺鐵黃化變小現象，供給鐵肥則黃化現象消失。此一缺鐵現象，當是廢棄金針菇木屑堆肥含量豐富之水溶性磷與鐵形成複合物沈澱，鐵之有效性降低或有效性錳含量過高，鐵／錳不平衡導致，如表 5 、 6 所示，有待進一步探討。而黃[2]及楊[4]亦曾發現以廢棄金針菇木屑堆肥爲木瓜、山櫻花以及蕃茄育苗出現新葉缺鐵黃化現象，供給鐵肥則黃化現象消失。

表 5. 不同介質之水溶性化學分析

Table 5. The content of various water soluble nutrients in three different media.

Media	NH_4-N	P	K	Ca	Mg	Fe	Mn	Cu	Zn^z	pH	EC
	ppm					ppm					ds/m
JMWC	22.0	14.2	564.5	1,829.8	799.0	1.18	13.65	0.17	0.50	8.2	5.6
WMWC	1,305.0	4,755.5	6,150.0	125.0	489.6	26.65	70.61	0.17	25.94	6.4	5.4
Florafleur 001J	27.0	196.5	4,373.0	1,027.5	199.2	39.15	13.98	0.70	2.46	5.8	1.9

^{z} Extracted by the 0.1M HCl.

表 6. 不同育苗介質、洋香瓜瓜苗葉片之化學分析比較

Table 6. Comparison of the leaf analysis of muskmelon seedlings planted between two different seed-sowing media.

Media	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
	%					ppm			
WMWC	4.25	1.51	5.59	0.67	1.98	173.9	706.8	15.5	131.0
Florafleur 001J	2.37	0.41	2.99	3.80	0.63	153.5	81.2	3.4	73.8

二、不同育苗介質比較試驗

廢棄金針菇木屑堆肥物理性甚佳，爲一理想育苗介質；但其 $EC_{1:5}$值高達5.4ds/m，且尙存養分不平衡現象。試以添加部份粉碎稻殼於該介質中以降低介質生產成本；並根據堆肥理化性質分析及觀察試驗中瓜苗呈現之葉片養分缺乏症狀及葉片分析，調整堆肥理化性質，添加碳酸鈣以補充鈣素，添加硫酸亞鐵以改善瓜苗缺鐵現象。以堆肥、粉碎稻殼、碳酸鈣、硫酸亞鐵四種材料，不同比率、濃度混合，不完全組合設計，選得兩種最佳混合比率之介質配方，並同兩種不同進口培養土於春作進行育苗比較試驗，而秋作育苗試驗不再引用進口培養土 BVB 2，因其春作之表現不及另一進口培養土 Florafleur 001J。另以純廢棄金針菇木屑堆肥爲對照，處理如表 2 所示，結果顯示：廢棄金針菇木屑堆肥添加20%或40%粉碎稻殼；此一介質 1 公升，混以 5 克碳酸鈣及 5 克硫酸亞鐵的兩種處理，初期瓜苗生育遲緩，但後期乾物重均較以純廢棄金針菇木屑堆肥育苗者增加，達 5 %顯著差異水準，可與以進口培養土育苗者相較，如表 7 、圖 1 所示。

表 7. 不同處理之廢棄金針菇木屑堆肥與進口培養土對洋香瓜瓜苗生長之影響（1996年春、秋作）

Table 7. Effect of the winter mushroom waste (sawdust) compost with various treatments and commercial media on the growth of muskmelon seedlings (Spring and Autumn crops of 1996).

Media	Shoot wt.	Root wt.	Total dry wt.
	mg/plant		
	Spring cropping[x]		
WMWC	75.7±19.0 d[z]	15.9± 3.7 c	91.6±18.6 d
WMWC+20%RH(Ca、Fe)[y]	412.9±33.0 c	50.0± 6.5 b	462.9±34.6 bc
WMWC+40%RH(Ca、Fe)	391.4±35.3 c	63.9± 8.0 a	455.3±30.7 c
Florafleur 001J	581.4±78.8 a	42.1±12.5 b	623.6±81.4 a
BVB 2	464.3±22.3 b	46.9± 6.6 b	511.2±28.0 b
	Autumn cropping[x]		
WMWC	183.8± 56.3 b	20.7± 4.0 c	204.4± 59.7 b
WMWC+20%RH(Ca、Fe)	820.0±181.3 a	71.6±18.7 a	891.6±198.6 a
WMWC+40%RH(Ca、Fe)	833.8±152.5 a	83.7±26.2 a	917.4±176.7 a
Florafleur 001J	885.0±213.3 a	46.1±12.3 b	931.1±221.9 a
BVB 2	—[w]	—	—

z Means in each column followed by the same letters are not significantly different at 5% level (Duncan's Multiple Range Test).

y WMWC+20%RH (Ca、Fe): WMWC blended with 20% milled rice hulls and $CaCO_3$、$FeSO_4$ added.
WMWC+40%RH (Ca、Fe): WMWC blended with 40% milled rice hulls and $CaCO_3$、$FeSO_4$ added.

x Muskmelon seedlings planted for 21 days in late April and for 19 days in early September, respectively.

w No cropping.

圖 1. 廢棄金針菇木屑堆肥添加40%粉碎稻殼之育苗配方與純廢棄金針菇木屑堆肥及進口培養土於春作洋香瓜瓜苗生育之比較。

Fig. 1. Comparison of growth of seedlings in spring among the winter mushroom waste (sawdust) compost blended with 40% milled rice hulls and fertility properly regulated, pure unblended winter mushroom waste (sawdust) compost and imported growing media.

根據該二作瓜苗生育情形，秋作僅針對較佳育苗配方二種及較適宜之進口培養土（Florafleur 001J）一種所育成之瓜苗，進行定植後植株之生育比較試驗。結果顯示，秋作定植後，植株明顯比以進口培養土育苗者健壯，如表 8 、圖 2 所示，此差異推測是該堆肥含豐富之水溶性銨態氮、磷、鉀、鎂，本身又兼具緩效性肥料，當瓜苗定植後，可持續供應植株養分，如同起始肥料（Starter fertilizer），促進根群初期延展。而以進口培養土所育之瓜苗生育雖佳，但定植後培養土所含養分已不敷瓜苗利用，需賴追肥供應，故瓜苗定植後，植株明顯比以進口培養土育苗者健壯；另於此配方中，粉碎稻殼20%或40%添加量，對於瓜苗或定植後植株生育，並無明顯差異，故可增添粉碎稻殼用量達40%，減少堆肥用量以降低成本。因此之故，以廢棄金針菇木屑堆肥及粉碎稻殼調配洋香瓜育苗介質實為可行。

表 8. 廢棄金針葉木屑堆肥育苗配方與進口培養土對秋作洋香瓜瓜苗定植後植株之生育比較

Table 8. Effect of the winter mushroom waste (sawdust) compost with different formulas, and commercial media on the growth of muskmelon seedlings transplanted in autumn.

Media	Days after transplanting					
	10 days			15 days		
	Plant height	Leaf length	Leaf width	Plant height	Leaf length	Leaf width
	cm					
WMWC+20%RH(Ca、Fe)[y]	57±7 a[z]	9.4±0.7 a	12.3±0.8 a	93±4 a	9.9±0.7 a	13.5±0.3 a
WMWC+40%RH(Ca、Fe)	50±7 b	9.3±0.4 a	11.9±0.6 a	90±9 a	9.9±0.3 a	13.4±0.3 a
Florafleur 001J	44±2 b	7.1±0.5 a	9.7±0.8 b	70±5 b	7.8±0.7 b	11.1±1.1 b

[z] Means in each column followed by the same letters are not significantly different at 5% level (Duncan's Multiple Range Test).
[y] See Table 7 for composition of media.

表 8. (續)

Table 8. (Continued)

Media	Days after transplanting			
	23 days			
	Plant height	Leaf length	Leaf width	Shoot dry wt.
	cm			g/plant
WMWC+20%RH(Ca、Fe)	175± 5 a	12.1±0.5 a	16.0±0.6 a	21.87±1.87 a
WMWC+40%RH(Ca、Fe)	170± 4 a	12.1±0.4 a	15.8±0.3 a	21.36±2.06 a
Florafleur 001J	147±15 b	10.2±0.6 b	13.5±1.4 b	13.17±2.50 b

圖 2. 廢棄金針菇木屑堆肥添加40%粉碎稻殼之育苗配方與進口培養土於秋作洋香瓜瓜苗定植後10日，植株之比較。

Fig. 2. Comparison of growth of seedlings transplanted 10 days later in autumn between the winter mushroom waste (sawdust) compost blended with 40% milled rice hulls and fertility regulated, and imported growing media.

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Assessment of Mushroom Waste (Sawdust) Compost as Muskmelon Seed-Sowing Media[1]

Ming-Hui Chang, Wei-Min Hsiang, Shiuan-Yuh Chien and Wei-Tin Huang[2]

Summary

Mushroom production in Taiwan has generated tremendous volume of spent mushroom composts. Attempts were made trying to reutilize those composts, including recycling use as seed-sowing media The feasibility was first assessed based on the determined physical and chemical properties of the composts. Plug systems were applied to compare the effects of various media (with different ratios of rice hulls added) on the nursery growth of muskmelon (*Cucumis melo* L. var. reticulatus Naud) in spring and autumn seasons. The experimental results are summarized as follows:

1. Waste composts for growing Jew's ear and oyster, with fertility corrected and wetting agents added, were sparingly satisfactory as muskmelon seed-sowing media. But its easy available water was still low, demanding frequent irrigation during nursery management. Because of fine texture and poor rewtting nature, the media became sticky when wet and irreversible when dry. These composts were practically not ideal media for seed-sowing of muskmelon.

The media prepared from the waste winter mushroom composts had better aeration. It contained abundant amounts of water soluble NH_4-N、P、K and Mg. EC value was high (5.4ds/m, 1：5w/w). Water soluble Ca was lower as compared to that of the imported media tested. Leaf Ca of muskmelon seedlings was generally low. There was iron chlorosis in new leaves emerged after cotyledons. Through proper fertility correction such as adding $CaCO_3$ and $FeSO_4$, The media were still suitable for muskmelon seedling cultivation.

2. If muskmelon seedings were grown in winter mushroom composts blended either with 20% or 40% of milled rice hulls (V/V), with 5g $CaCO_3$ and 5g $FeSO_4$ added in 1 liter of media, plant dry weight of the treatments was obviously higher than the control (no rice hulls and chemicals blended). The difference was significant at 5% level. The effect of fertility corrected on muskmelon seedlings was competitive to that of imported media.

Key words: Mushroom waste (sawdust) compost, Muskmelon seed-sowing media, Physical and chemical properties.

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廢棄香菇木屑堆肥研製及對小白菜之肥效[1]

簡宣裕[2]　莊作權[3]

摘要：本研究目的爲探討將廢棄香菇木屑與雞糞以三種不同比例配方混合後研製堆肥，瞭解堆肥化過程的成分變化，及不同肥培對小白菜生長的影響。結果顯示於發酵過程中，大致三種配方之 pH、全氮濃度均逐漸增加，電導度先下降然後再上升，有機碳含量與碳氮的比値、氨氣濃度逐漸減少。木屑與雞糞依乾重以16：4或32：4混合者，氨氣濃度顯著較少，且可在八星期內趨近於穩定腐熟。

三種配方堆肥的 pH 値、全氧化鈣濃度、全氧化鎂濃度相近，電導度、全氮濃度、全磷濃度及全鉀濃度，則以配方 A （8：4）＞配方 B（16：4）＞配方 C（32：4）順序遞減。將堆肥施入土壤，前三天內土壤的微生物菌數最多。盆栽試驗結果獲知配方 A 堆肥最有利於小白菜生長，其次爲配方 B 堆肥。盆栽土壤3kg 施用12g 堆肥，若把堆肥養分(氮、磷、鉀)含量，按1／5或1／2爲有效養分估算，然後以化學肥料補足，相當于每盆施用 0.360g 有效性氮、0.215g 磷酐、0.288g 氧化鉀，進行盆栽試驗，小白菜產量皆比只施用化學肥料者高，且達顯著差異水準。

關鍵詞：堆肥化、廢棄香菇木屑堆肥、小白菜。

臺灣一年栽培菇類之後廢棄木屑有119,250公噸，其中廢棄香菇木屑量爲54,000公噸，所佔的比例最大[(6)]。大部份的菇類栽培期皆集中於秋天至春天之間，在晚春至初夏時菇農將廢棄木屑清出菇舍，故這段時間有大量且集中的廢棄木屑產生。以前菇農對廢棄菇類木屑的處理方式大多採取直接傾倒於窪地、河道或偏僻小道的方式或如同燃燒稻草的習慣在空地處加以焚燒，如此不但將寶貴的有機物資源浪費掉，而且造成環境的污染[(12)]。

食用菇類栽培過程可能夾帶如 *Fusarium*、*Trichoderma*等雜菌[(11)]，此些微生物對於作物的生長可能是有害的[(14)]，故不加以堆肥化就直接施用，會使作物發生病害的機率增加，且廢棄菇類木屑的纖維素、有機碳含量高，雖可資源化再循環利用，但因還含有許多易被微生物利用的有機物，若不加以處理就施用於土壤，則微生物的族群會迅速繁衍[(15)]，造成與作物競爭養分、作物根部周圍溫度太高及缺乏氧氣[(19)]而窒息，故廢棄菇類木屑最好先與含氮量高的雞糞（表4）混合，以降低碳氮的比例，提供氮源供發酵過程中微生物使用，加速堆肥化，使其性質穩定化後再使用，較爲妥當。本研究目的爲觀察堆肥化過程的成分變化，以瞭解木屑與雞糞於製造堆肥時，較合適的混合比例，及探討此堆肥對作物生長的影響，擬將試驗所得的資料提供給農民參考採用，希望因此可以解決廢棄菇類木屑污染環境的問題，亦能有益於土壤生產力的提升。

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材料與方法

一、廢棄香菇木屑堆肥之研製

有三種配方研製堆肥（82年9月至82年12月），即配方 A：木屑＋雞糞（8：4，w／w），配方B：木屑＋雞糞（16：4），配方 C：木屑＋雞糞（32：4），木屑主要來自桉樹等闊葉樹種，二重複。每配方堆積量爲6公尺（長）×5公尺（寬）×1.5公尺（高），水分含量調爲60%左右，堆積處底下有通風管送風，送風量爲100公升／分鐘，每立方公尺，每隔二十五分鐘送風五分鐘，每星期用鏟裝機翻堆一次，定期取樣。

測定項目：1. pH 及電導度，按樣品與水以1：5充分攪拌混合後一小時，分別以玻璃電極酸鹼度計及電導度計測定。2. 全磷、全鉀，以二酸法分解，磷以鉬酸銨顯色法顯色後，用光電比色器測定，鉀用火燄分光儀測定[10]。3. 全氮，樣品以濃硫酸及催化劑分解[10]後，用擴散法測定。4. 有機碳，以濕化法（wet combustion method）測定[20]。5. 氨氣，以北川氏氣體檢知管[17]，測定發酵中堆肥材料正上方之氨氣濃度。6. 土壤微生物菌數測定：堆肥與土壤以1：100混合，調水分爲20%、40%，置於25°C培養箱，在0天、1天、3天、5天、14天、35天取樣，樣品經適當稀釋，取0.1mL 稀釋液，用三角玻棒均勻塗抹於營養肉汁洋菜（NA）平面培養基及馬鈴薯洋菜（PDA）平面培養基，分別培養細菌及眞菌，於25°C培養箱培養七天後，計算培養基上的菌數[25]。

二、不同成分堆肥對小白菜（*Brassica chinensis* L. Makino）生長之影響

㈠施肥處理：

三種配方堆肥（成分如表1），各有四種施肥處理，如表2所列：

施肥處理Ⅰ（Treatment Ⅰ）：3kg 盆栽土壤施用12g 堆肥，將堆肥養分含量按1／5爲有效養分估算，然後以化學肥料補足。施肥處理Ⅱ（Treatment Ⅱ）：3kg 盆栽土壤施用12g 堆肥，將堆肥養分含量按1／2爲有效養分估算，然後以化學肥料補足。施肥處理Ⅲ（Treatment Ⅲ）：3kg 盆栽土壤施用12g 堆肥。施肥處理Ⅳ（Treatment Ⅳ）：3kg 盆栽土壤施用化學肥料。處理Ⅰ、處理Ⅱ及處理Ⅳ均相當於每盆施用0.360g 氮、0.215g 磷酐、0.288g 氧化鉀。化學肥料採用尿素、過磷酸鈣、氯化鉀。盆栽土壤取自農業試驗所21號田區，土壤性質如表3所列。

表 1. 廢棄香菇木屑堆肥的養分濃度

Table 1. Nutrient composition of shiitake sawdust waste composts

Recipe	pH	E. C.[z] mmhos/cm	T.N. (%)	P_2O_5 (%)	K_2O (%)	CaO (%)	MgO (%)	O. C. (%)
A	8.6a[y]	4.6a	2.46a	4.33a	2.26a	9.63a	0.17a	28.0b
B	8.6a	4.1a	2.37a	4.19a	2.23a	9.12ab	0.16a	28.2b
C	8.3a	3.4b	2.25b	3.99b	2.18a	8.70b	0.15a	30.7a

[z] E. C.：Electrical conductivity. T. N.: Total nitrogen. O. C.: Organic carbon.

[y] ：Mean values in the same column followed by the same letter are not significantly different (P>0.05) as determined by the Duncan test.

表 2. 施肥處理

Table 2. Fertilizer application treatments.

Treatment[z]	Recipe A compost applied (g/pot)			Chemical fertilizer applied (g/pot)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
I	0.221	0.389	0.204	0.316	0.137	0.247
II	0.221	0.389	0.204	0.250	0.020	0.186
III	0.221	0.389	0.204	0	0	0
IV	0	0	0	0.360	0.215	0.288
Treatment	Recipe B compost applied (g/pot)			Chemical fertilizer applied (g/pot)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
I	0.213	0.378	0.201	0.317	0.139	0.248
II	0.213	0.378	0.201	0.254	0.026	0.188
III	0.213	0.378	0.201	0	0	0
IV	0	0	0	0.360	0.215	0.288
Treatment	Recipe C compost applied (g/pot)			Chemical fertilizer applied (g/pot)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
I	0.203	0.360	0.196	0.319	0.143	0.249
II	0.203	0.360	0.196	0.259	0.035	0.190
III	0.203	0.360	0.196	0	0	0
IV	0	0	0	0.360	0.215	0.288

[z] Treatment I : Compost mineralization rate was estimated by 1/5.
Treatment II : Compost mineralization rate was estimated by 1/2.
Treatment III : Compost mineralization rate was estimated by 100%.
Treatment IV : Check.

表 3. 試驗土壤之性質

Table 3. Soil properties of the experiment.

pH	O. M. (%)	Bray No. 1 P (ppm)	Exchangeable K (ppm)	Texture
5.2	1.8	10	55	Silt Loam

(二)產量調查及植體養分測定：

盆栽種植小白菜（83年5月4日），三重複。植後第三十五天採收，做產量調查及植體全氮、全磷及全鉀濃度的測定，化驗分析方法同上述測定堆肥樣品者。

結果與討論

一、廢棄香菇木屑堆肥化過程的成分變化

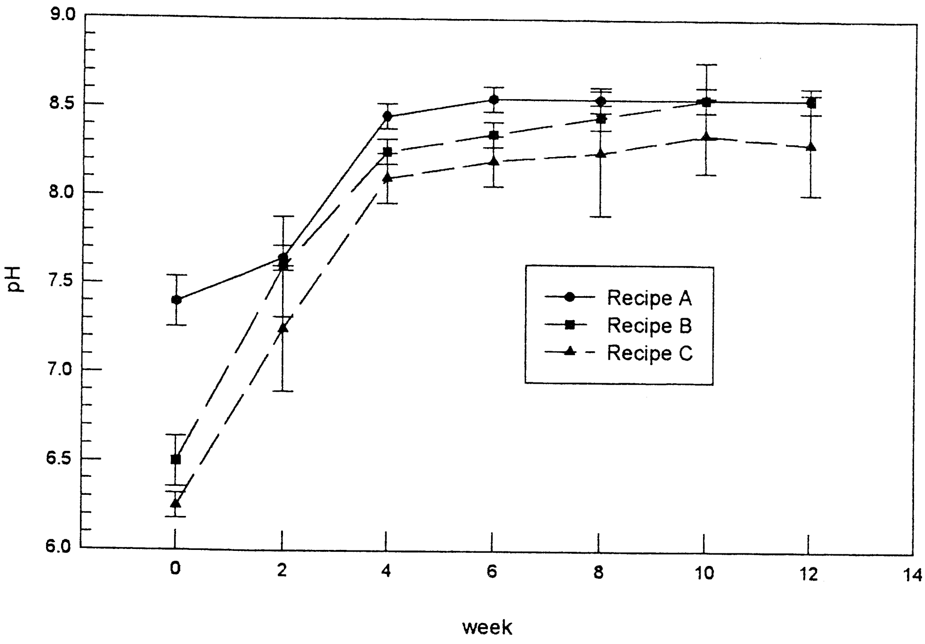
堆肥化過程中，堆肥材料的pH隨時間而增加，四星期後三種配方的pH皆高於8.0，其後酸鹼度漸趨於穩定而相近（圖1）。廢棄香菇木屑在堆肥化過程pH上升，與三種配方皆添加氮及鈣含量高的雞糞（表4）有關。前四星期，有機氮經由旺盛的脫氨作用（deamination）[13,16]釋出大量氨氣，造成鹼性的劇增，且雞糞中鈣含量高亦有利鹼性的形成，pH因而上升。配方A之pH高於配方B及配方C，是配方A添加較多量雞糞所致。

表 4. 廢棄香菇木屑及雞糞的養分濃度

Table 4. The composition of shiitake sawdust waste and chicken feces

Material	pH	E. C.[z] mmhos/cm	T. N. (%)	P_2O_5 (%)	K_2O (%)	CaO (%)	MgO (%)	O. C. (%)
Chicken feces	8.7a[z]	11.4a	2.80a	4.20a	4.37a	20.30a	0.22a	34.4a
Sawdust	5.6b	2.8b	1.25b	1.62b	0.76b	2.98b	0.08b	44.6b

[z] E. C. : Electrical conductivity. T. N.: Total nitrogen. O. C.: Organic carbon.
[y] Mean values in the same column followed by the same letter are not significantly different ($P>0.05$) as determined by the LSD test.



Recipe A: sawdust+chicken feces(8:4). Recipe B: sawdust+chicken feces(16:4).
Recipe C: sawdust+chicken feces(32:4).

圖 1. 廢棄香菇木屑於堆肥化過程中pH 的變化

Fig. 1. Changes in pH of shiitake sawdust waste during composting.

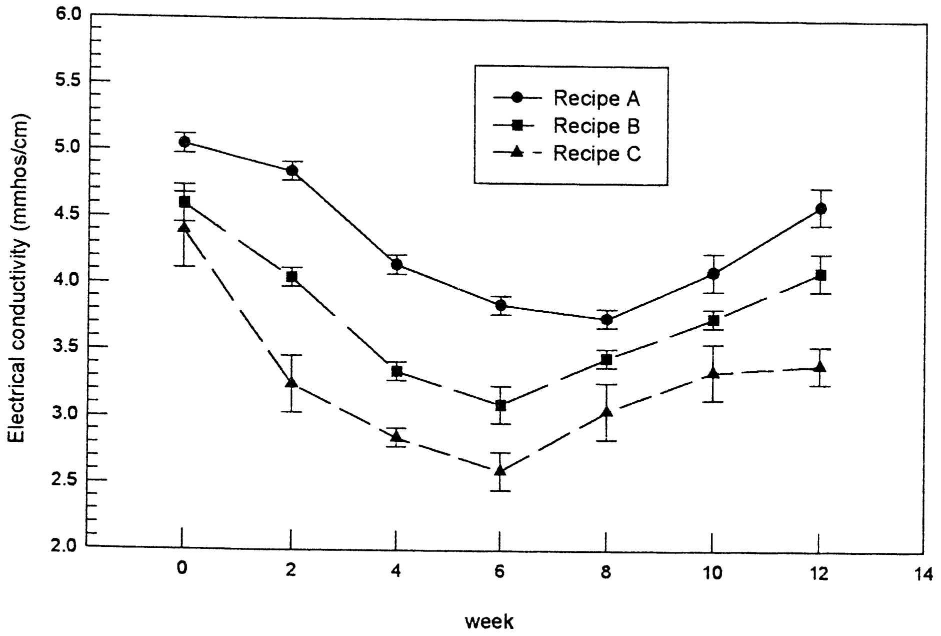
三種配方的電導度皆先下降，至第六星期之後才有再上升的趨勢（圖2）。電導度先下降然後再上升的現象，原因可能是剛開始堆肥化時，堆肥材料中含有較多的無機養分，故電導度較高，但隨著堆肥化過程的進行，無機養分被微生物吸收利用而濃度逐漸減少，電導度相對的逐漸下降，微生物繁衍至某一階段後族群數會減少[7,13]部份菌體死亡分解後釋出無機養分，故此時無機養分的濃度、鹽類濃度又提高[2,6]，使電導度測值上升。三種配方隨著木屑與雞糞混合比例的增加而電導度減小（圖2），此與木屑使用量增加，雞糞比例減少，造成雞糞的稀釋作用有關（表4）。配方 A、配方 B 所製造出來的堆肥，電導度皆超過4.0 mmhos／cm，故在施用時需要考慮堆肥使用量的限制，以避免過度施用，造成鹽害，反而不利作物生長。

有機碳含量隨時間增加而減少，配方 A 有機碳含量在前四星期內變化大，配方 B、配方 C則至

第八星期時才有較大的變化（圖3）。配方 A 有機碳含量減少速度遠比配方 B、配方 C 快，此與配方 A 添加較多量雞糞有關，雞糞所含之有機碳較容易被微生物當做碳源[2,6,7]，有利於菌株族群的繁衍，故有機碳被分解的速度會較快。總體而言三種配方的全氮濃度，依雞糞與木屑混合比例愈大，則濃度愈高，且隨著時間而升高（圖4）。全氮濃度在發酵後第三天時減少，至第七天時才回復接近原來濃度，然後隨著時間而增高，此現象是發酵初期氨氣的揮發損失[3]過快，而使全氮的濃度暫時下降。三種配方處理在發酵過程中，皆有氨氣揮發損失（圖5），但是堆肥材料中有機物被分解、代謝掉的速度可能遠超過氨的揮發損失，故全氮濃度有逐漸上升的趨勢。

有機碳與全氮的比值，隨時間而減少[2,6,7]，配方 A 者在四星期內迅速減小，配方 B、配方 C 在八星期內變化較大，然後趨向於平穩（圖6）。由上述試驗的結果，可以大致推斷廢棄香菇木屑和雞糞以8：4相互混合，在發酵條件良好情況下，可望在四星期後達到穩定，而趨於腐熟。適量氮源的添加對於加速廢棄菇類木屑的堆肥化是必要的，若氮源添加量不足或不添加氮源，則堆肥化所需要的時間會較長，至少要八星期。

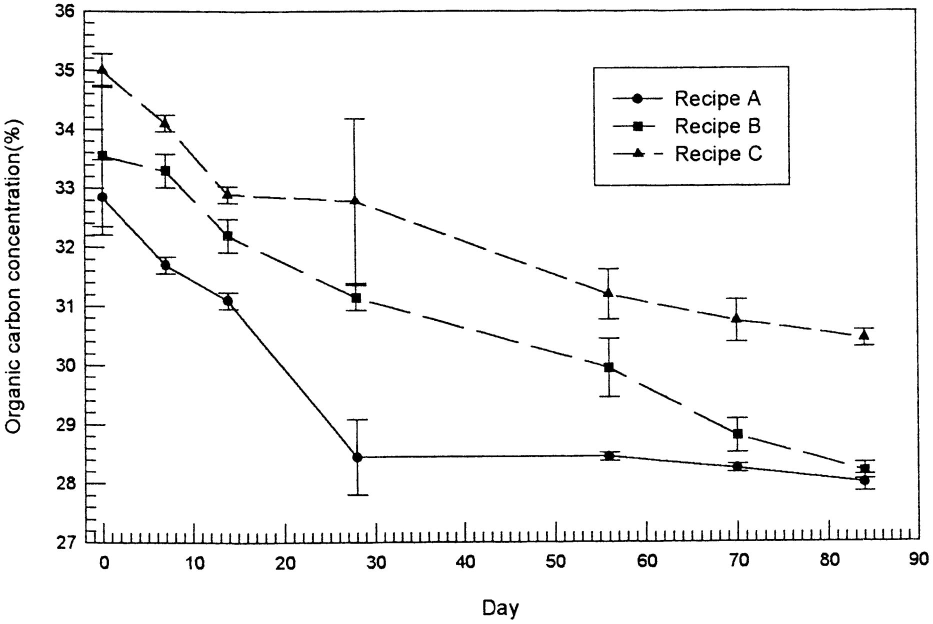
氨氣濃度於前六星期內較高，於堆肥化過程中，廢棄香菇木屑與雞糞以16：4或32：4比例混合比以 8 ： 4 比例混合，能顯著減少氨氣的產生(圖5)，此與木屑添加量愈多，愈能吸收愈多氨氣有關[8]。



Recipe A: sawdust+chicken feces(8:4). Recipe B: sawdust+chicken feces(16:4).
Recipe C: sawdust+chicken feces(32:4).

圖 2. 廢棄香菇木屑於堆肥化過程中電導度的變化

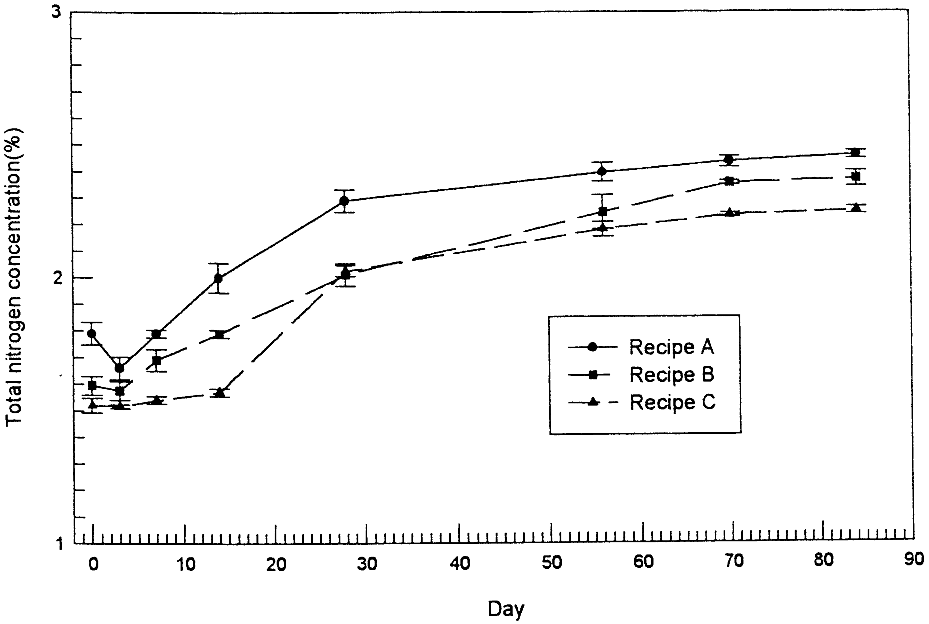
Fig. 2. Changes in electrical conductivity of shiitake sawdust waste during composting.



Recipe A: sawdust+chicken feces(8:4). Recipe B: sawdust+chicken feces(16:4).
Recipe C: sawdust+chicken feces(32:4).

圖 3. 廢棄香菇木屑於堆肥化過程中有機碳濃度的變化

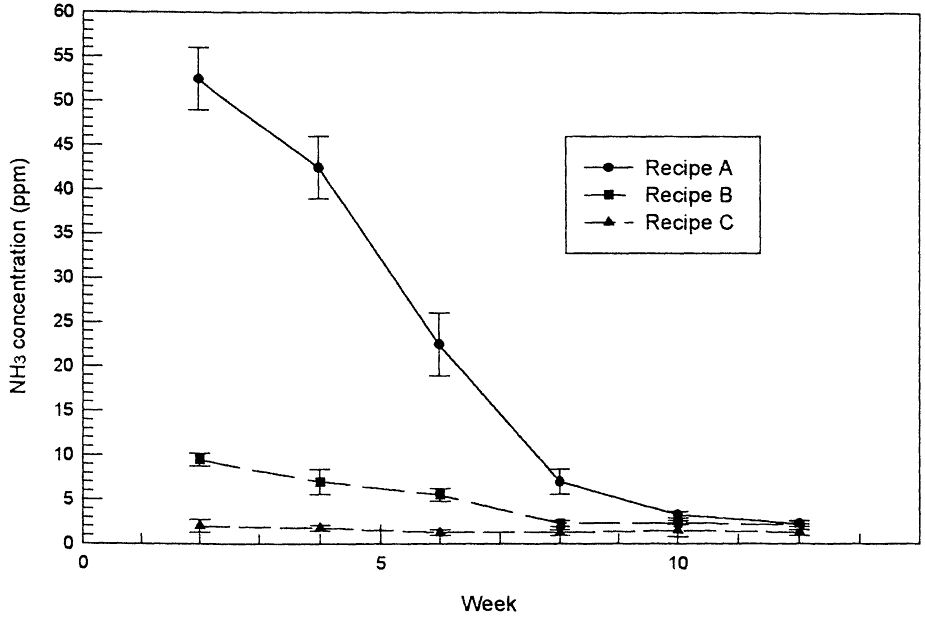
Fig. 3. Changes in organic carbon concentration of shiitake sawdust waste during composting.



Recipe A:sawdust+chicken feces(8:4). Recipe B:sawdust+chicken feces(16:4).
Recipe C:sawdust+chicken feces(32:4).

圖 4. 廢棄香菇木屑於堆肥化過程中全氮濃度的變化

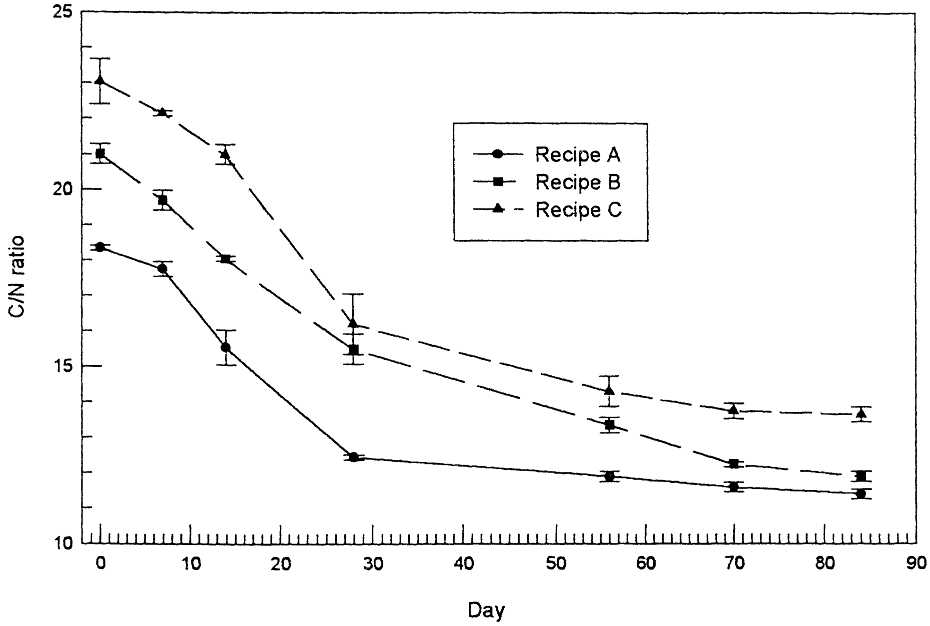
Fig. 4. Changes in total nitrogen concentration of shiitake sawdust waste during composting.



Recipe A: sawdust+chicken feces(8:4). Recipe B: sawdust+chicken feces(16:4).
Recipe C: sawdust+chicken feces(32:4).

圖 5. 廢棄香菇木屑於堆肥化過程中氨氣濃度的變化

Fig. 5. Changes in ammonia gas concentration of shiitake sawdust waste during composting.



Recipe A: sawdust+chicken feces(8:4). Recipe B: sawdust+chicken feces(16:4).
Recipe C: sawdust+chicken feces(32:4).

圖 6. 廢棄香菇木屑於堆肥化過程中碳氮比值的變化

Fig. 6. Changes in C/N ratio of shiitake sawdust waste during composting.

二、堆肥施入土壤對土壤微生物菌數之影響

將配方 B 堆肥與土壤混合後，調水分含量爲20%或40%，然後測定土壤微生物菌數。試驗結果得知20%水分含量遠比40%水分含量有利於微生物的生長，堆肥加入土壤可以顯著增加微生物菌數，且以細菌爲主，眞菌數目每克土壤皆低於10^4 CFU。20%水分含量的土壤於第一天時，微生物菌數最高，至第三天則急速變小，在二星期後每克土壤的微生物菌數小於10^6 CFU（圖7），此與在前二星期內，有外來有機物可供微生物利用，而使土壤微生物活性顯著提高[5,15,18]有關。

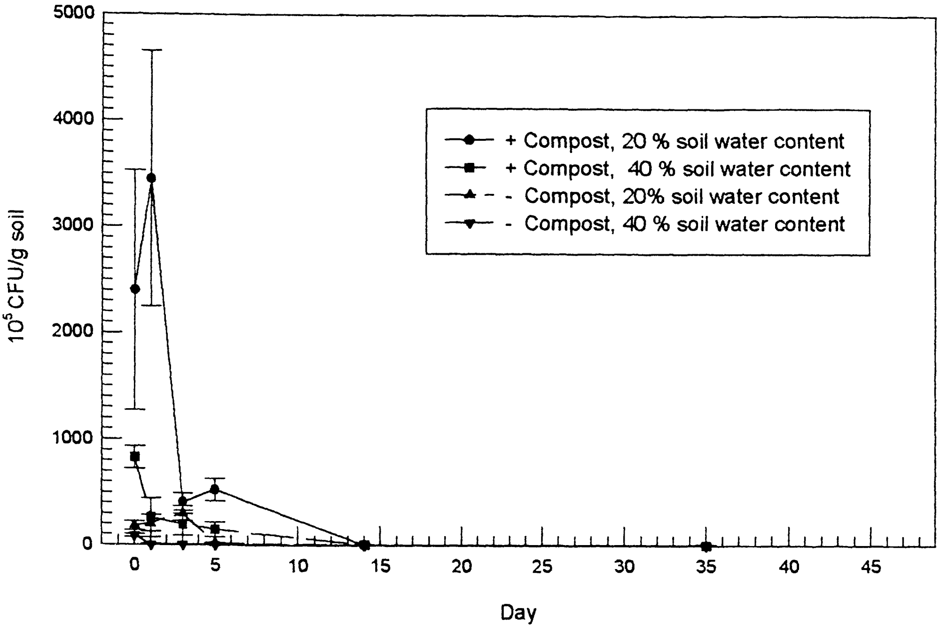


圖 7. 配方 B 堆肥施入土壤後土壤微生物菌數的變化

Fig. 7. Changes in microorganism population of soil incorporated with recipe B compost.

三、廢棄香菇木屑堆肥對小白菜生長之效應

每株小白菜的重量，以配方 A 堆肥者比配方 B 堆肥者及配方 C 堆肥者爲重，此與配方 A 堆肥所含的養分濃度高於配方 B 堆肥、配方 C 堆肥有關（表5）。

表 5. 三種配方堆肥配合化學肥料施用對小白菜株重（公克／株）的影響

Table 5. The weight of *Brassica chinesis* as affected by application of shiitake sawdust waste composts with chemical fertilizer added (g/plant).

Treatment[z]	Recipe A compost		Recipe B compost		Recipe C compost	
	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
I	63.7a[y]	3.9a	63.8a	3.9a	66.9a	3.9a
II	57.4a	3.5a	60.0a	3.6a	60.8b	3.5b
III	26.5c	1.7c	18.1c	1.3c	15.1d	1.7d
IV	35.6b	2.5b	35.6b	2.5b	35.6c	2.5c

[z] Treatment I, Treatment II, Treatment III, Treatment IV, same as table 2.
[y] Mean values in the same column followed by the same letter are not significantly different (P>0.05) as determined by the Duncan test.

試驗期間，若將三種配方堆肥養分（氮、磷、鉀）含量，按1／2或1／5爲有效養分估算，然後以化學肥料補足，相當于每盆施用0.360g 有效性氮、0.215g 磷酐、0.288g 氧化鉀（相當于每公頃施用300kg 有效性氮、179kg磷酐、240kg 氧化鉀）（表2），試驗結果得知每株小白菜鮮重皆分別比只施用化學肥料者爲重，小白菜乾重亦有相同的趨勢（表5），此由於生長期間堆肥可供小白菜吸收利用的有效養分量，遠大於全養分量的1/2，及木屑堆肥具有膨鬆性質，可以增進土壤通氣性、保水能力及生物活性[21]，故因而促進土壤的生產力[4,24]所致。

試驗結果，獲知只施化學肥料處理（施肥處理Ⅳ）的小白菜氮及鉀濃度，遠高於只施堆肥處理者（施肥處理Ⅲ），且可達二倍之多（表6、表8），只施堆肥處理小白菜的氮濃度、鉀濃度，處於氮及鉀缺乏範圍（deficiency range），此時氮及鉀成爲小白菜生長的限制因子（limiting factor），小白菜的生理機能因氮、鉀要素不足而無法順利進行，而影響作物的生長[1,9]。小白菜磷的濃度，施堆肥處理者皆高於只施肥化學料處理者（表7），但只施堆肥處理的小白菜株重卻顯著小於只施化學肥料處理者，顯示磷的效應不顯著，含量均已達豐富範圍，而氮與鉀之效應非常明顯，成爲影響之重要因子（表5、表6、表8）。

施肥處理Ⅰ與施肥處理Ⅱ小白菜的氮濃度及鉀濃度顯著高於只施堆肥處理者，而施肥處理Ⅰ、施肥處理Ⅱ小白菜的磷濃度低於只施堆肥處理者，但施肥處理Ⅰ、施肥處理Ⅱ小白菜的氮濃度、磷濃度、鉀濃度皆與只施化學肥料處理者植體養分的濃度接近（表6、表7、表8），且小白菜的株重以施肥處理Ⅰ＞施肥處理Ⅱ＞只施化學肥料處理＞只施堆肥處理（表5），顯示施肥處理Ⅰ、施肥處理Ⅱ小白菜的氮、磷及鉀濃度已達到適合小白菜生理機能需要的正常濃度。

施肥處理Ⅰ、施肥處理Ⅱ、及只施化學肥料處理小白菜植體的氮濃度：磷濃度：鉀濃度爲10至12：1：16至19，而只施堆肥處理小白菜植體的氮濃度：磷濃度：鉀濃度爲4至5：1：11（表6、表7、表8），顯然只施堆肥處理小白菜植體氮濃度與鉀濃度的比例偏低，又由表 1 的資料知道三種配方堆肥的氮濃度：磷濃度：鉀濃度都接近於1.3：1：1，比起適合一般蔬菜生長的氮濃度：磷濃度：鉀濃度爲5至6：1：6至8[22,23]來講，堆肥磷濃度的比例偏高，而氮濃度與鉀濃度的比例則偏低。故三種配方堆肥若配合化學氮肥及鉀肥的施用，顯然可增進小白菜氮、鉀的吸收量，而有利於小白菜養分的平衡，使小白菜的產量增加，但加施化學磷肥對小白菜磷的吸收，及促進小白菜的生長，則可能效益比較少。

表 6. 三種配方堆肥配合化學肥料施用對小白菜氮濃度的影響

Table 6. The nitrogen concentration of *Brassica chinesis* as affected by application of shiitake sawdust waste composts with chemical fertilizer added.

Treatment	Recipe A compost N (%)	Recipe B compost N (%)	Recipe C compost N (%)
Ⅰ	4.9ab[z]	5.0a	5.2a
Ⅱ	4.5b	4.9a	4.9a
Ⅲ	2.9c	2.6b	2.3b
Ⅳ	5.1a	5.2a	5.1a

[z] Mean values in the same column followed by the same letter are not significantly different (P>0.05) as determined by the Duncan test.

表 7. 三種配方堆肥配合化學肥料施用對小白菜磷濃度的影響

Table 7. The phosphorus concentration of *Brassica chinesis* as affected by shiitake sawdust waste composts with chemical fertilizer added.

Treatment	Recipe A compost P (%)	Recipe B compost P (%)	Recipe C compost P (%)
I	0.49b[z]	0.46b	0.50b
II	0.46b	0.45b	0.47b
III	0.59a	0.59a	0.57a
IV	0.42c	0.42c	0.41c

[z] Mean values in the same column followed by the same letter are not significantly different (P>0.05) as determined by the Duncan test.

表 8. 三種配方堆肥配合化學肥料施用對小白菜鉀濃度的影響

Table 8. The potassium concentration of *Brassica chinesis* as affected by shiitake sawdust waste composts with chemical fertilizer added.

Treatment	Recipe A compost K (%)	Recipe B compost K (%)	Recipe C compost K (%)
I	7.8a[z]	5.0a	5.2a
II	7.7a	4.9a	4.9a
III	6.4b	2.6b	2.3b
IV	7.6a	5.2a	5.1a

[z] Mean values in the same column followed by the same letter are not significantly different (P>0.05) as determined by the Duncan test.

結論與建議

廢棄香菇木屑與雞糞以16：4的比例相互混合，進行發酵製造堆肥，可望在八星期內趨近穩定腐熟，而且使氨揮發損失及氨氣臭味減低。三種配方堆肥的氮、磷及鉀養分濃度的比例，顯然磷的含量偏高，需要配合氮肥、鉀肥的施用，才能滿足作物生長養分平衡的需要，有關作物生長期中養分平衡與施肥配合，堆肥養分礦化率評估、堆肥施入土壤中引起酵素活性、生質量的變化情形，有待進一步深入的試驗研究予以探討。

誌　謝

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Composting Shiitake Sawdust Waste and Effects of Applied Composts on Growth of *Brassica chinensis* L. Makino[1]

Shiuan-Yuh Chien[2] and Tzo-Chuan Juang[3]

Summary

The objective of this study was to investigate the composition changes of shiitake sawdust waste composting with chicken feces at different rates, 8 : 4 (recipe A) , 16 : 4 (recipe B), and 32 : 4 (recipe C) , and the effect of application of composts on the growth of *Brassica chinensis* L. Makino.

Composting changes in pH, total N, organic C and C/N for the recipes had similar trends. Compost pH increased with time, and reached above 8.0 after 4 weeks of composting. Total nitrogen concentration started to increase 3 days after composting and leveled off after 4 weeks. Organic carbon content and C/N ratio reduced subsequently with time. Electrical conductivity decreased initially, but increased at 6 weeks after composting. NH_3 gas concentrations of recipe B and recipe C were significantly lower than that of recipe A.

pH, CaO, MgO contents of the composts of 3 recipes were similar, but electrical conductivity as well as percent N, P_2O_5 and K_2O of the composts were in the order of recipe A> recipe B>recipe C. Soil microorganism population reached to the highest level within 3 days when recipe B compost was applied to soils.

It is found that recipe A compost was more suitable for *B. chinensis* growth than those of recipe B and recipe C composts. The pot experiment also showed that the growth of *B. chinensis* with application of 12 g compost/pot was significantly lower than that of the chemical fertilizer treated plot, to which 0.360g N/pot, 0.215 g P_2O_5/pot and 0.288g K_2O/pot were applied.

Key words: Composting, Shiitake sawdust waste compost, *Brassica chinensis* L. Makino.

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應用非線性迴歸方法於土壤吸附重金屬動態反應模式之參數決定[1]

劉滄棽[2]　林正錺[3]

摘要：本研究針對溶質輸送現象及表面化學中，常被引用之非線性吸附反應為對象，利用統計和數值方法研究模式參數鑑定的方法，嘗試檢視並改進各種傳統鑑定方法可能隱含的誤差，以有效規範系統反應行為。

本研究使用吸附能力不同的四個大度山紅壤分別與 50ppm 和 100ppm 的銅離子或鎘離子溶液混合，在吸附反應的過程中，測定未平衡狀態不同時間的金屬離子濃度，可以得到動態吸附現象的數據。利用數值分析軟體，求解非線性動態吸附方程式的參數，探討求解條件，及參數在吸附反應中的意義。

由研究結果得知，三種模式所得之曲線代表性均高（>0.95），但以擬二級吸附反應（pseudo second order adsorption reaction）在部分試驗數據求得之最大吸附量竟小於觀測得到的吸附量，顯示擬二級吸附反應不能完全代表土壤與離子吸附反應的現象。經加入反應級數修正後的模式，則均未發現此不合理的狀況。

同一試驗條件在不同時間下取得之數據，因本身之自相關（autocorrelation）太大，所求得之參數雖可將數據模擬得十分吻合，但參數的偏差太大，因此仍不能得到有代表性的參數。在本研究中，最大吸附量（R）至少要有兩組不同濃度條件的動態吸附數據，才能使所得的參數有意義，反應吸數（n）則至少需要四組以上不同反應條件的數據，而反應速率常數（k）需要八組以上不同反應條件的數據，才能使所得的參數有意義。

關鍵詞：參數鍵定、微分方程式、模式。

自從 Forrester[15,16] 及 Meadow et al.[29] 等，麻省理工學院為首的學者，提出動態系統分析方法與概念之後，系統分析與模擬研究，隨著數位計算機的發展，在各領域都有廣泛的應用，在生物與環境科學方面的研究自不例外[11,14,21]。

目前國內也有部分土壤學者從事利用動態系統分析方法進行生物環境系統分析模擬工作[1,2,6,22,23,24,25,26,27]。這些研究工作應用系統分析方法所建立的系統模式，有屬於簡單之非線性代數式者，也有屬於非線性常微分方程式組，甚至有屬於非線性偏微分方程式組者，就參數及狀態變數種類而言，甚至有屬於非線性偏微分方程式組者，就參數及狀態變數種類而言，有的系統僅有兩個參數，兩個變數，有的則高達數十個參數與狀態變數。參數較少的系統模式可藉試驗設計及統計方法的輔助求取參數值，但參數多，且部分變數為不可測得之系統模式，則僅能以試誤法求取為主。試誤法固然可

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行但其缺點在於不易確定所得之解是否具廣泛之代表性，而且無法規範出一定的法則，成為擴展應用上的阻礙。目前國外在生物環境方面的系統分析工作也仍侷限在這個範圍為主，但有部分學者則早已注意這個問題[31,32,34]。

從連續性線性模式本身的數學性質看來，系統分析者所遭遇的問題，也就是以非線性微分方程式組的問題為首。這類性質的模式，在工程數學上相關性的問題很多，而且大部分都可以近似法求得解決，許多參考文獻都有詳盡分析。但工程上的問題與生物環境方面的問題有截然不同的特性，其差異在於許多工程系統參數都有明確定義，並有一定測量方法[13,31]，而生物環境系統變因很多，而且不易做定量測試[34]，或甚至有無法測量之變數或參數者[19,28]。因此直接引用工程數學方面的系統分析工具仍有其限制，必須依賴使用者對問題的了解，並透過試驗設計方法，輔助設立解析之條件。此直接引用工程數學方面的系統分析工具仍有其限制，必須依賴使用者對問題的了解，並透過試驗設計方法，輔助設立解析之條件。

無論所建立的模式規模是大或是小，其中必定包含或多或少的參數值，參數值之設定就是一個重要的分析工作。就實際意義而言，所謂參數值的意義與設定，以 Langmuir Adsorption Isotherm 為例，其中的最大吸附量與吸附能量就是系統參數；以 Michalis-Menton Equation 為例，其中的最大反應速率常數及半反應速率常數對應之基質濃度常數值，就是系統參數；又例如達西定律中之導水係數或同位素退變之半衰期常數，也都是模式參數的一種。這些簡單模式之變數及參數少又單純，且為穩定狀態方程式，藉數學轉換的技巧，可以明確的找到特定條件下的參數值。然而當系統模式逐漸複雜，為使其適用性擴大，而增加變因之後，系統變數或參數亦隨著增加。所建立之模式如又以動態分析為目的，則模式中各參數的鑑定，已非簡單之轉換方法可以解決，況且，在土壤環境問題這方面之研究工作以動態系統分析理念進行者，尚不多見。固然有部分土壤學者結合其他學者所進行之所謂作物生長模式之建立[20,36]，然而其中當仍有許多機制與參數待進一步鑑定。這方面的動態系統模式參數之鑑定，除了學理上有明確定義，可以進行測量者外，目前許多由於測量不易及誤差不易控制的參數仍以試誤法為主要檢定方法。

有關土壤一水複合物的模式包括兩方面，第一方面是溶質在土體中的移動模式；第二方面是溶質在移動過程中的理化反應模式。溶質在土體中移動之模式型態屬拋物線型偏微分方程式（parabolic partial differential equation），已廣泛被接受且使用，並已有多種方法可以鑑定在飽和或不飽和流動狀態下之系統參數[8,9,10,12,17,18,30,33,35]；溶解質在移動過程中的理化反應模式則有平衡反應和動態反應模式，二者都有相當多的假說，而有不同型態的模式被討論和應用。

溶質在土壤中的理化反應，在上述土壤一水複合物模式中佔有重要的地位，因為其反應速率直接影響溶質在土體中的移動速率及移動量。林與陳[2]曾就重金屬在土壤中滯留在自污泥中釋出之反應提出一動態模式，其後並對模式中影響反應參數的因子進行修正[3,5,6]，同時也利用此一模式模擬土壤中肥料養分反應現象[7]。此動態模式因係非線性微分方程式，雖然在特定假設條件下可以動態模擬法解連立方程式求出反應速率常數，但求得之參數有隨反應時間及溶液濃度不同而改變的缺點[4]，經修正後的模式更增加了次方位置的參數，使參數鑑定工作更困難，往往只能以試誤法得到參數。

本文即為解決鑑定動態吸附模式參數時，非線性微分式組參數求解的問題，並消除反應濃度對反應速率常數之影響，故測定未平衡狀態溶液中之離子濃度，利用數值分析軟體，探討在模式修正後之非線性方程式求解條件，同時比較參數數目的多寡對參數鑑定的影響，及各參數在吸附反應中的意義。

材料與方法

一、材　料

採樣地點位於東海大學旁之臺中工業區內，整個採樣區面積約16公頃，形狀近似梯形，坡度平緩

，採樣時已經整平，爲雜草地，土地利用形態均勻，土壤屬大肚山紅壤。

本試驗中選擇以銅離子和鎘離子爲試驗對象。同時希望能瞭解吸附能力不同的土壤，在動態吸附時的表現，因此由過去的資料中選取對銅吸附量最小的土壤樣品編號1，吸附量最大的樣品編號2，對鎘吸附量最小的樣品編號3，和對鎘吸附量最小的樣品編號3，和對鎘吸附量最大的樣品編號3，共四個土壤樣品進行試驗。

二、設計與方法

(一)由於本研究中僅考慮反應濃度和土壤性質的影響，因此所有試驗均在相同溫度、水土比等環境條件下進行。

(二)由前人研究中已知道土壤的吸附反應極爲迅速，在兩小時內即趨向平衡，本研究則希望能取得未平衡狀態下溶液中之離子濃度，爲使反應在瞬間停止，需迅速分離溶液和土壤粒子，所以過濾時使用抽氣裝置。

(三)爲取得未平衡狀態溶液中之離子濃度，故需在反應進行過程中取出溶液，但使用震盪器時，取出樣品需費較多時間，不易計取得較短時間之數據，所以在實驗中 5 分鐘以內之樣品以手搖，20分鐘以上之樣品則以震盪器震盪。

(四)以 100ppm 之 Cu^{2+}、Cd^{2+} 標準溶液稀釋，製備 50ppm 和 100ppm 之 Cu^{2+}、Cd^{2+} 溶液。

(五)取 10g 土置於 50ml 塑膠廣口瓶中，加入 50ml 溶液震盪，每組實驗之設計條件列於表1 。

(六)於約1、2、5、20、40及60分鐘取出懸浮液過濾，並以碼錶計算時間。

(七)取濾液以原子吸光儀測定濾液中 Cu^{2+}、Cd^{2+} 離子濃度。

表 1. 實驗條件

Table 1. Experimental conditions

Experimental code	Ion	Concentration	Soil no.
1	Cu	50ppm	1（銅吸附量少）
2	Cu	50ppm	2（銅吸附量多）
3	Cu	100ppm	1（銅吸附量多）
4	Cu	100ppm	2（銅吸附量少）
5	Cd	50ppm	3（鎘吸附量少）
6	Cd	50ppm	4（鎘吸附量多）
7	Cd	100ppm	3（鎘吸附量多）
8	Cd	100ppm	4（鎘吸附量少）

三、模式理論

根據化學動力學和物質反應原理，以及前人研究所建立之模式，假設土壤與離子反應之機制爲單一步驟可逆反應，其模式爲

$$Mi + S \underset{K_2}{\overset{K_1}{\rightleftharpoons}} Mi - S$$

其反應動力式表示如下：

$$\frac{\partial Mi}{\partial t} = -K_1\rho(Mi)(R-MiS) + \rho/\theta K_2(MiS) \quad \cdots\cdots (1)$$

$$\frac{\partial MiS}{\partial t} = -K_1\theta(Mi)(R-MiS) + K_2(MiS) \quad \cdots\cdots (2)$$

MiS：吸附在土壤表面的溶質（$\mu g/g$）

Mi：土壤溶液中溶質的含量（$\mu g/m^3$）

R：土壤表面最大吸附量（$\mu g/g$）

θ：含水量（ml/cm^3）

ρ：總體密度（g/cm^3）

K_1、K_2：反應速率常數

以上動力學模式係基於下列幾點假設：

1. 反應離子在系統中分爲水溶液相與吸附相兩種。
2. 反應速率方程式爲 pseudo second order equation。
3. 模式中（R-MiS）作爲土壤吸附不飽和度的機制。

在反應平衡時，即$\frac{\partial Mi}{\partial t}=0$ 時(1)、(2)式與 Langmuir adsorption isotherm 模式之數學方程式相同。由陳[6]之研究中得知，前述反應速率方程式求出之反應速率常數常爲變數，而林等[4,5]認爲若修正爲非線性方程式可以把實驗結果模擬得更好。修正後的方程式如下：

$$\frac{\partial Mi}{\partial t}=-K_1\theta^{n1-1}(Mi)^{n1}[\rho(R-MiS]^{n2}+K_2(\rho MiS)^{n3}/\theta \quad \cdots\cdots(3)$$

$$\frac{\partial MiS}{\partial t}=K_1\theta^{n1}(Mi)^{n1}\rho^{n2-1}(R-MiS)^{n2}-K_2\rho^{n3-1}(MiS)^{n3}/\theta \quad \cdots\cdots(4)$$

n_1、n_2、n_3：反應參數

在(3)、(4)式中若 n_1、n_2、n_3 皆等於1，即爲(1)、(2)式。又若 n_1、n_2、n_3 爲相等但不一定爲 1 的數值，則當$\frac{\partial Mi}{\partial t}=0$時仍與 Langmuir adsorption isotherm 模式之數學方程式相同。

在前述研究中多以 CEC 爲土壤的最大吸附量（R），事實上R值可能因選擇性吸附或多層吸附等因素而不等於 CEC，因此本文在模式中將R視爲變動之參數，並就以下幾種情況進行參數求解，並加以比較：

1. $n_1\neq n_2\neq n_3\neq 1$　模式一
2. $n_1=n_2=n_3\neq 1$　模式二
3. $n_1=n_2=n_3=1$　模式三

四、參數鑑定方法

由觀測得到的數據來求解非線性方程式參數，主要係根據最小平方和法，求使離差平方和最小的參數，即爲最佳參數值。

假設非線性方程式系統 $\underline{f}(\underline{x})=\underline{0}$，其中

$$\underline{f}=[f_1,f_2,\cdots f_n],\underline{x}+[x_1,x_2,\cdots x_k]$$

欲求$\underline{x}$，使之能最小化$F(\underline{x})$

$$F(\underline{x})=\sum_{i=1}^{n}[f(\underline{x})]^2。$$

設有$\underline{x}$使$\frac{\partial F(\underline{x})}{\partial x_j}=0$，$j=1,2,\cdots,K$，則 $\underline{x}$ 即爲所求，成爲非線性方程式組求解問題。在實際求解參數時除考慮求解方法外，也要考慮所得參數是否具有物理意義，以及在使用參數進行預測時是否有代表性。

(一)Powell 演算法（Powell's algorithm）

Powell 演算法是綜合應用 Gauss-Newton 和 steepest descent 的方法去求解非線性方

程式組。 Gauss-Newton 和 steepest descent 法二者均是利用 Jacobian 矩陣（J），其定義爲

$$J_{ij}=\frac{\partial f_i}{\partial x_j}。$$

在當時估計值（current estimated）爲x時之 Gauss-Newton 校正值（v）爲 $v=-J^{-1}\underset{\sim}{f}$，而 steepest descent 的校正值（g）爲 $g=-J^T\underset{\sim}{f}$。在每次重覆運算時 $\underline{v}$ 及 $\underline{g}$ 二者均會被計算，同時實際校正值（δ）也會在其中被使用，此實際校正值（actual estimated）爲 $\underline{v}$ 及 $\underline{g}$ 二者之線性結合。精確的線性結合決定於當時校正步驟的範圍（△）。

實際校正值（$\underset{\sim}{\delta}$）受當時校正步驟的範圍（△）的控制，一般而言有三種情況：

(1)如果$\Sigma \underline{V}^2 \leqq \triangle$然後讓$\underset{\sim}{\delta}=\underline{V}$，此時是在解(solution)的附近，則使用 Gauss-Newton 校正；

(2)如果$\underline{x}$在 steepest descent 方向上之預測最小值的距離大於 △($\mu\Sigma g^2 \geqq \triangle$)，此時設定 $\underset{\sim}{\delta}=\triangle g/\Sigma g^2$，所預測的最小值在 $\underset{\sim}{x}+\mu g$，而$\mu=\Sigma g^2/\Sigma(Jg)^2$；

(3)如果不是上述二情況時，則選擇$\underset{\sim}{\delta}$爲μg與$\underline{V}$的線性結合（$\underset{\sim}{\delta}=(1-\theta)\mu g+\theta)\underline{V}$，使得$\Sigma\underset{\sim}{\delta}^2=\triangle$。

由上述可了解在運算過程中△是一重要的數量指標，△越大則越能快速達到收斂。因此 Powell 的策略是評定 Jacobian 去預測 $F(\underset{\sim}{x}+\underset{\sim}{\delta})$的能力和使△之值盡可能的大使得 $F(\underset{\sim}{x}+\underset{\sim}{\delta})$ 的 Jacobian 預測變爲合宜。因此如果 $F(\underset{\sim}{x}+\underset{\sim}{\delta})>F(\underset{\sim}{x})$（此校正導致較差的$\underline{x}$估計），則△會變小；同樣地，如果F的減少比預期要小的很多的話，△也會變小。所使用之評斷標準如下：設F爲給定校正情況之的預測平方總合，也就是

$$\Phi=\Sigma(\underset{\sim}{f}+J\underset{\sim}{\delta})^2$$

然後如果

$$F(\underset{\sim}{x})-F(\underset{\sim}{x}+\underset{\sim}{\delta})<0.1\times(F(\underset{\sim}{x})-\Phi)$$

△的大小會被減半。因此由 Jacobian 去預測之F至少會減少10%。

(二)參數求解與數據之設定

本研究使用 SCIENTIST 軟體作爲參數求解的工具，此一軟體進而在兩個領域上擴充了原 Powell 演算法的領域，一是在方程式組多過未知數的情況下，去求得離差平方合最小化的解；另一是在問題本身包含數量差距極大幅度的參數時，可自動訂定出變數分布的範圍，使得演算變爲更有效率。此外在特定的情況下，可限定已知參數的值或值之分布範圍，以減少重覆演算的時間。

將八組實驗所得之數據分別代入上述三個模式，由 SCIENTIST 軟體進行參數逼近解得之反應參數列於表2。爲瞭解溶液中離子起始濃度對反應參數的影響，將同一土壤樣品，同一金屬離子，不同起始反應濃度之數據合併於同一資料庫，假設其反應參數不受反應物濃度或反應時間的影響，以 SCIENTIST 軟體進行參數逼近，解得之反應參數列於表3。再將同一金屬離子，不同土壤樣品，不同起始反應濃度之數據合併於同一資料庫，假設其反應參數相同但不同土壤有不同的最大吸附量，以 SCIENTIST 軟體進行參數逼近，解得之反應應參數列於表4。最後爲測試模式是否可以同時模擬不同離子與不同土壤的吸附現象，甚至將所有數據合併，解得之反應參數亦列於表4。

表 2. 不同離子、不同濃度、不同土壤實驗結果，以三種模式解得之參數值及決定係數

Table 2. Estimated parameters and coefficient of determination by three models of different ions, concentrations, and soils.

code	model	k_1	k_2	n_1	n_2	n_3	R	r^2
	1	2.337E-05	8.454E-03	1.283	1.230	0.914	314.251	0.987
		(1.824E-01)	(7.183E+01)	(9.360E+03)	(8.283E+03)	(2.126E+03)	(1.191E+06)	
1	2	1.057E-04	3.650E-03	1.115			220.248	0.987
		(5.132E-03)	(2.062E-02)	(3.475)			(3,775.754)	
	3	1.905E-04	7.272E-03				278.573	0.986
		(1.048E-03)	(2.308E-02)				(1,363.982)	
	1	2.446E-05	2.609E-03	1.169	1.255	1.259	466.530	0.997
		(6.981E+00)	(7.812E+02)	(5.714E+04)	(8.044E+04)	(1.132E+05)	(6.842E+08)	
2	2	5.294E-05	3.777E-03	1.146			402.647	0.997
		(2.137E-03)	(5.177E-03)	(2.128)			(7,095.288)	
	3	1.354E-04	7.770E-04				499.211	0.997
		(4.891E-04)	(8.340E-03)				(1,9347.802)	
	1	2.383E-05	1.767E-02	1.241	1.169	1.137	629.883	0.966
		(3.183E-03)	(6.399E+00)	(9.553E+02)	(9.283E+02)	(7.920E+01)	(1.414E+05)	
3	2	9.144E-06	1.143E-02	1.268			809.722	0.965
		(1.346E-03)	(7.721E-01)	(16.115)			(9,492.640)	
	3	7.148E-04	1.706E-03				165.148	0.967
		(2.083E-03)	(1.160E-01)				(398.084)	
	1	4.499E-05	9.757E-03	1.109	1.273	1.260	572.896	0.972
		(9.441E-03)	(5.174E+00)	(2.812E+03)	(2.783E+03)	(1.227E+02)	(1.134E+05)	
4	2	3.173E-05	1.259E-02	1.209			669.829	0.972
		(4.350E-03)	(3.039E-01)	(8.993)			(26,721.630)	
	3	9.015E-04	3.932E-04				203.206	0.972
		(2.699E-03)	(1.247E-01)				(464.002)	
	1	7.932E-01	9.559E-01	0.793	0.956	0.880	2,690.592	0.994
		(2.345E-05)	(7.718E+04)	(2.345E+05)	(7.718E+04)	(2.236E+03)	(4.832E+09)	
5	2	2.343E-05	1.370E-02	0.997			3,614.335	0.994
		(1.184E-01)	(8.023E+00)	(1.623E+02)			(1.203E+07)	
	3	2.510E-05	1.415E-02				3,417.317	0.994
		(7.152E-03)	(9.857E-02)				(9.614E+058)	
	1	4.440E-05	5.95E-03	1.636	1.127	0.852	384.769	0.999
		(5.721E-02)	(2.467E+02)	(1.606E+04)	(1.798E+04)	(1.181E04)	(4.659E+06)	
6	2	6.043E-04	5.498E-03	1.004			342.546	0.999
		(3.173E-02)	(9.854E-02)	(5.180)			(3,933.652)	
	3	6.215E-04	5.574E-03				341.528	0.999
		(3.745E-03)	(1.571E-02)				(1,398.237)	
	1	3.958E-06	1.708E-03	1.391	1.316	1.333	834.432	0.945
		(6.760E-03)	(1.606E+00)	(1.092E+03)	(1.092E+03)	(2.405E+02)	(8.282E+05)	
7	2	5.270E-06	1.746E-03	1.329			785.286	0.945
		(2.224E-03)	(2.495E-01)	(35.793)			(49,576.706)	
	3	4.248E-01	1.061E-04				253.034	0.947
		(3.292E-04)	(8.695E-03)				(140.315)	
	1	2.695E-05	5.748E-03	1.116	1.135	1.202	2,055.433	0.978
		(8.533E-01)	(1.507E+02)	(1.816E+03)	(1.325E+03)	(6.066E+03)	(33.819E+07)	
8	2	2.406E-50	6.484E-03	1.161			1,738.226	0.978
		(8.629E-04)	(3.998E-02)	(1.633)			(28,493.458)	
	3	1.040E-04	1.499E-02				1,974.827	0.977
		(1.090E-03)	(1.750E-02)				(19,415.566)	

( ) : standard error of upper parameter

表 3. 相同土壤、相同離子不同濃度數據合併，以三種模式求解之參數值及決定係數

Table 3. Estimated parameters and coefficient of determination by three models of different ions, but same concentrations, and soils.

code	model	k_1	k_2	n_1	n_2	n_3	R	r^2
	1	1.493E−04	8.938E−02	1.241	1.116	0.230	191.072	0.995
1		(7.174E−04)	(1.162E−00)	(0.825)	(1.930)	(4.022)	(55.473)	
+	2	5.344E−10	2.771E−06	2.856			207.832	0.996
3		(1.456E−02)	(3.106E−06)	(0.125)			(15.834)	
	3	4.865E−04	1.305E−02				223.089	0.995
		(4.338E−05)	(1.271E−03)				(9.299)	
	1	7.197E−04	2.062E−03	1.293	0.596	1.443	228.838	0.994
2		(4.041E−02)	(5.348E−01)	(10.742)	(0.971)	(74.956)	(1,011.585)	
+	2	9.807E−11	6.762E−07	3.091			261.476	0.996
4		(1.361E−02)	(8.868E−07)	(0.151)			(22.257)	
	3	5.837E−04	1.371E−02				280.734	0.994
		(5.436E−05)	(1.304E−03)				(11.012)	
	1	9.943E−11	2.069E−03	1.685	2.871	1.248	1,463.628	0.972
5		(1.488E−01)	(1.175E−02)	(2.219)	(3.301)	(2.549)	(10,710.641)	
+	2	7.107E−07	7.236E−04	1.554			788.149	0.964
7		(3.138E−06)	(1.774E−03)	(0.512)			(280.451)	
	3	2.612E−05	1.210E−02				3,230.308	0.970
		(4.281E−05)	(1.283E−03)				(5,172.054)	
	1	1.344E−05	E3.840−03	1.154	1.561	1.181	692.690	0.988
6		(4.010E−04)	(4.371E−02)	(1.090)	(5.477)	(2.834)	(2,369.031)	
+	2	8.352E−07	1.554E−04	1.777			529.112	0.989
8		(2.288E−06)	(2.797E−04)	(0.351)			(40.710)	
	3	4.588E−04	9.557E−03				547.558	0.988
		(5.991E−05)	(8.440E−04)				(45.241)	

( ) : standard error of upper parameter

表 4. 相同離子、不同土壤、不同濃度實驗數據合併及所有數據合併，以三種模式求解之參數值及決定係數

Table 4. Estimated parameters and coefficient of determination by three models of combined data of same ions, different concentrations, different soil and total data respectively.

code	model	k_1	k_2	n_1	n_2	n_3	R				r^2
							soil 1	soil 2	soil 3	soil 4	
1 +	1	1.448E−13	9.917E−04	3.463	4.709	0.716	212.42	261.99			0.997
2 +		(7.767E−02)	(4.263E−03)	(1.237)	(2.610)	(1.403)	(28.93)	(29.93)			
	2	2.208E−10	1.170E−06	2.989			201.88	260.59			0.997
3 +		(1.181E−02)	(1.201E−06)	(0.115)			(13.65)	(16.97)			
	3	5.482E−04	1.341E−02				214.34	285.44			0.990
4		(3.445E−05)	(8.788E−04)				(5.94)	(8.16)			
5 +	1	3.334E−08	4.651E−03	1.136	1.920	1.220			3,604.23	5,395.01	0.977
6 +		(4.437E−02)	(9.236E−03)	(0.621)	(2.689)	(0.684)			(34,219.7)	(54,888.6)	
	2	2.219E−06	2.456E−03	1.328					1,488.12	2,754.74	0.977
7 +		(6.533E−06)	(3.930E−03)	(0.323)					(1,183.88)	(2,305.21)	
	3	3.022E−05	1,291E−02						2,943.92	5,757.59	0.969
8		(3.623E−05)	(9.070E−04)						(3,408.79)	(6,797.09)	
	1	1.126E−05	4.644E−03	1.421	1.409	1.141	258.01	338.29	428.93	702.17	0.987
total		(3.968E−05)	(7.258E−03)	(0.410)	(0.606)	(0.387)	(53.16)	(61.90)	(79.25)	(187.31)	
	2	6.492E−05	5.013E−03	1.200			256.66	343.55	442.27	751.00	0.987
data		(1.337E−04)	(6.166E−03)	(0.247)			(18.26)	(25.68)	(38.43)	(78.37)	
	3	3.485E−04	1.379E−02				260.48	350.58	455.12	783.80	0.986
		(2.874E−05)	(7.863E−04)				(13.28)	(18.43)	(27.52)	(54.37)	

( ) : standard error of upper parameter

結果與討論

本研究之主要目的在於瞭解修正後之非線性方程式是否可充份模擬動態吸附現象，並消除反應濃度對反應速率常數之影響。同時比較參數數目的多寡對參數求解的限制，及各參數在吸附反應中的意義。

一、三種模式對吸附反應的代表性

由表 2 可看出八組實驗所得結果分別代入上述三個模式，由 SCIENTIST 軟體進行參數逼近解得之反應參數，每組參數之 r^2 值都達到 0.95 以上。可知三種模式對單一條件下的吸附反應曲線均有相當代表性。三種模式間 r^2 值的關係以模式三的 r^2 值最高，模式一的 r^2 值最低。

表 3 所列爲將同一土壤樣品，同一金屬離子，不同起始反應濃度之數據合併於同一資料庫，進行參數逼近，可看到每組參數之 r^2 值仍可達到 0.95 以上。再將反應參數及起始條件代入模式，比較實驗所得離子濃度和由模式模擬所得（圖 1 至圖 3），三種模式對不同起始濃度的反應曲線，均有相當良好的模擬效果。三種模式間 r^2 值的關係亦以模式三的 r^2 值最高，模式一的 r^2 值最低。

表 4 所列爲將同一金屬離子，不同土壤樣品，不同起始反應濃度之數據合併，但不同土壤假設有不同的最大吸附量，進行參數逼近解得之反應參數。每組參數之 r^2 值仍可達到 0.95 以上，三種模式間 r^2 值的關係亦以模式一的 r^2 值最高，模式三的 r^2 值最低。將反應參數及起始條件代入模式，比較測定所得離子濃度和由模式模擬所得，Cu 離子之實驗結果和模式模擬之反應曲線亦頗爲符合（圖 4），但 Cd 離子之反應曲線有一組（條件六）模擬值偏離觀測值（圖 5）。

再進一步將所有數據合併，同樣進行參數逼近求解（表 4），所得三種模式之 r^2 值雖然仍大於 0.95，但將反應參數及起始條件代入模式，比較測定所得和由模式模擬所得離子濃度（圖 6），可見到偏離的數據更多（條件二、五、六）。觀察表 2 中相同離子，不同土壤所得反應參數，在模式一和模式二中，各 n 值之差異不大，但 k_1/k_2 之差異可達 10 的四次方倍之多，可見此偏離的結果可能是不同土壤的平衡常數不同所致，反應級數的影響則較不明顯。

二、不同起始反應濃度對參數之影響

林、陳（1987）的研究中雖曾將反應速率常數（k_1、k_2），設爲土壤溶液中重金屬離子起始濃度的函數，本研究則進一步指出有效的參數鑑定可以整合起始條件的差異，使模式更具代表意義。由表 3 可看出將同一土壤樣品，同一金屬離子，不同起始反應濃度之數據合併進行參數逼近，解得之反應參數，每組參數之 r^7 值仍可達到 0.95 以上。將反應參數及起始條件代入模式，比較測定所得離子濃度和由模式模擬所得（圖 1），三種模式對不同起始濃度的反應曲線，均有相當良好的模擬效果。

在陳[6]的研究中，使用動態模擬法先由實驗結果求 $Mi=f(t)$ 之迴歸式，再對 t 求微分，當取不同時間之 $\frac{\partial Mi}{\partial t}$ 值進行求解時，得到不同的參數值（k_1、k_2）。林、陳[2]的研究中，使用相同的方法而利用起始濃度校正 k_1、k_2。但由以上的觀察可見在相同環境條件（溫度、水份含量、總體密度）下，起始濃度對反應參數應該不會造成影響。造成前人研究中動態模擬法不能有效估計反應速率的原因可能有以下三點：1. 研究中使用之模式爲未經修正之 pseudo second order equation；2. 假設土壤的最大吸附量爲 CEC；3. 研究中所使用之迴歸式爲 $Mi=EXP(A+Bt^{0.1}+Ct^{0.2})$，此迴歸式雖與實驗結果有相當高的代表性，但經微分後所得速率在代表濃度隨時間的變化率時，仍有可能造成很大的誤差。

三、求取參數的限制條件

由表 2 中各參數之估計值與標準偏差比較可知除少數例外，參數估值之變異範圍很大，使參數估值之 95%信賴區間往往包含 0，意即數據雖已多於求參數所需，所包含的資訊仍不足以準確地估計出

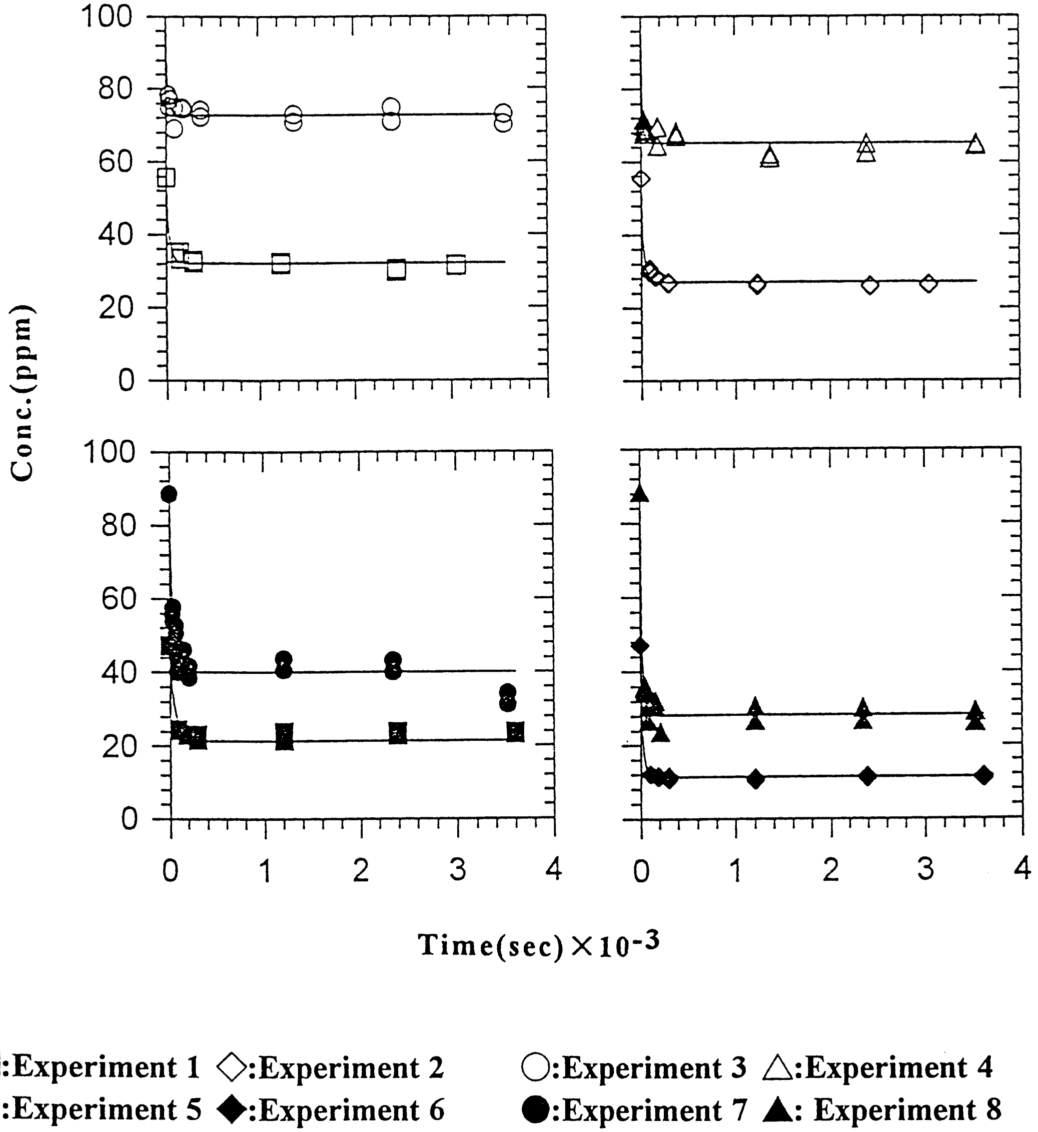
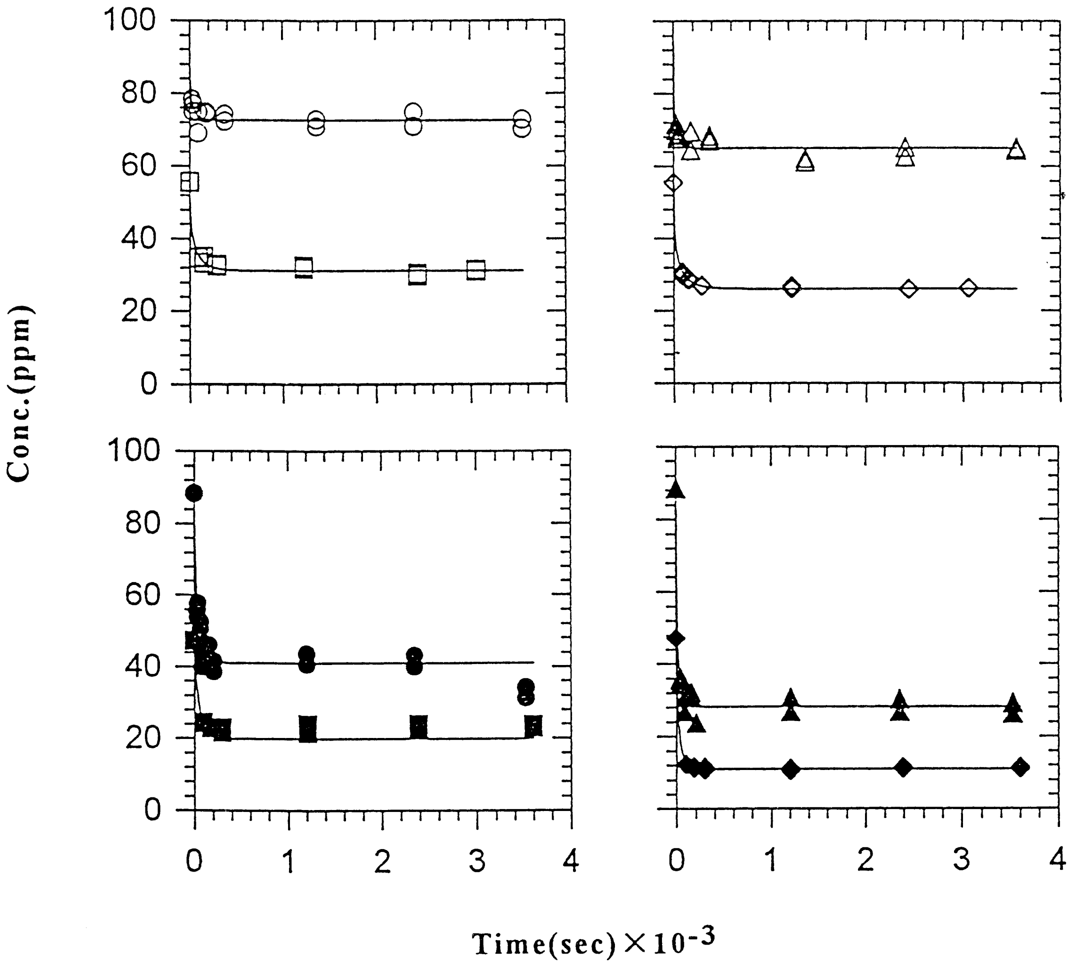


圖 1. 相同土壤、相同離子不同濃度實驗數據合併，以模式一模擬溶液中濃度隨時間變化情形……

Fig. 1. Combining simiar soil, similar ions, different concentration experimental data and use Model 1 to simulate concentration of solution changes with time.



□:Experiment 1 ◇:Experiment 2 ○:Experiment 3 △:Experiment 4
■:Experiment 5 ◆:Experiment 6 ●:Experiment 7 ▲: Experiment 8

圖 2. 相同土壤、相同離子不同濃度實驗數據合併，以模式二模擬溶液中濃度隨時間變化情形……

Fig. 2. Combining simiar soil, similar ions, different concentration experimental data and use Model 2 to simulate concentration of solution changes with time.

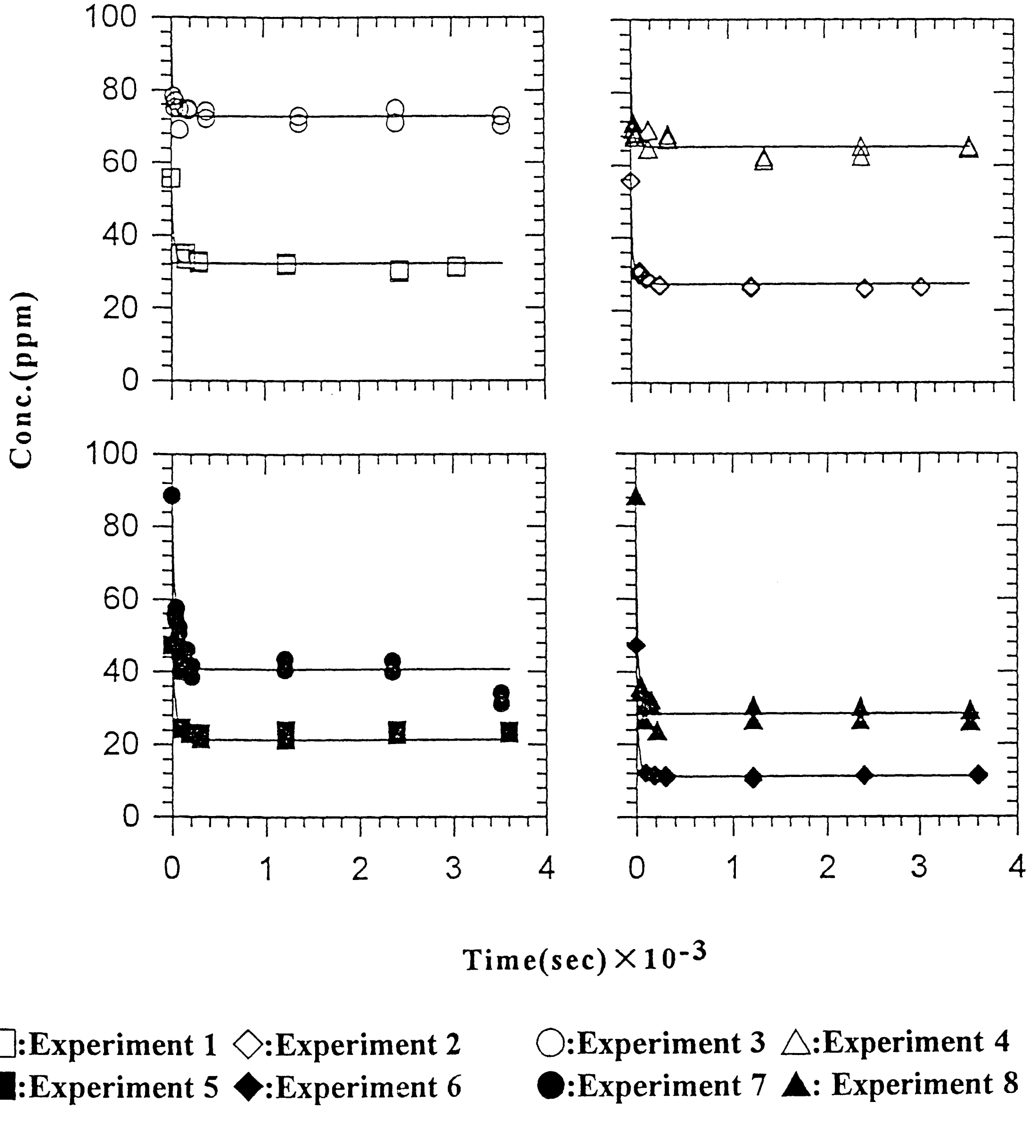


圖 3. 相同土壤、相同離子不同濃度實驗數據合併，以模式一模擬溶液中濃度隨時間變化情形……

Fig. 3. Combining simiar soil, similar ions, different concentration experimental data and use Model 3 to simulate concentration of solution changes with time.

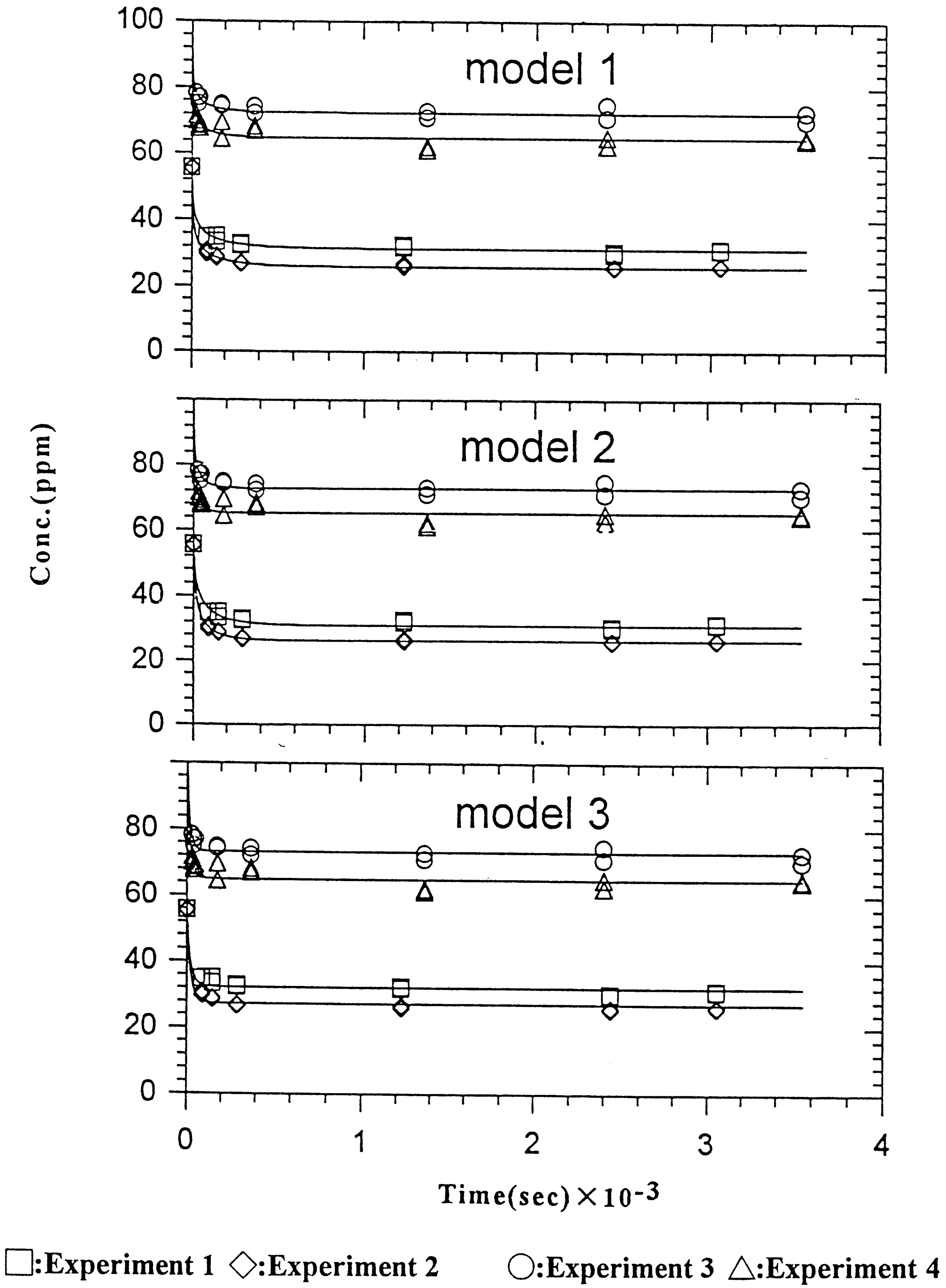


圖 4. 銅離子之不同濃度、不同土壤實驗數據合併，以三種模式模擬溶液中濃度隨時間變化情形……

Fig. 4. Combining different concentration of copper ions, different soil experimental data and using three models to simulate concentration of solution changes with time.

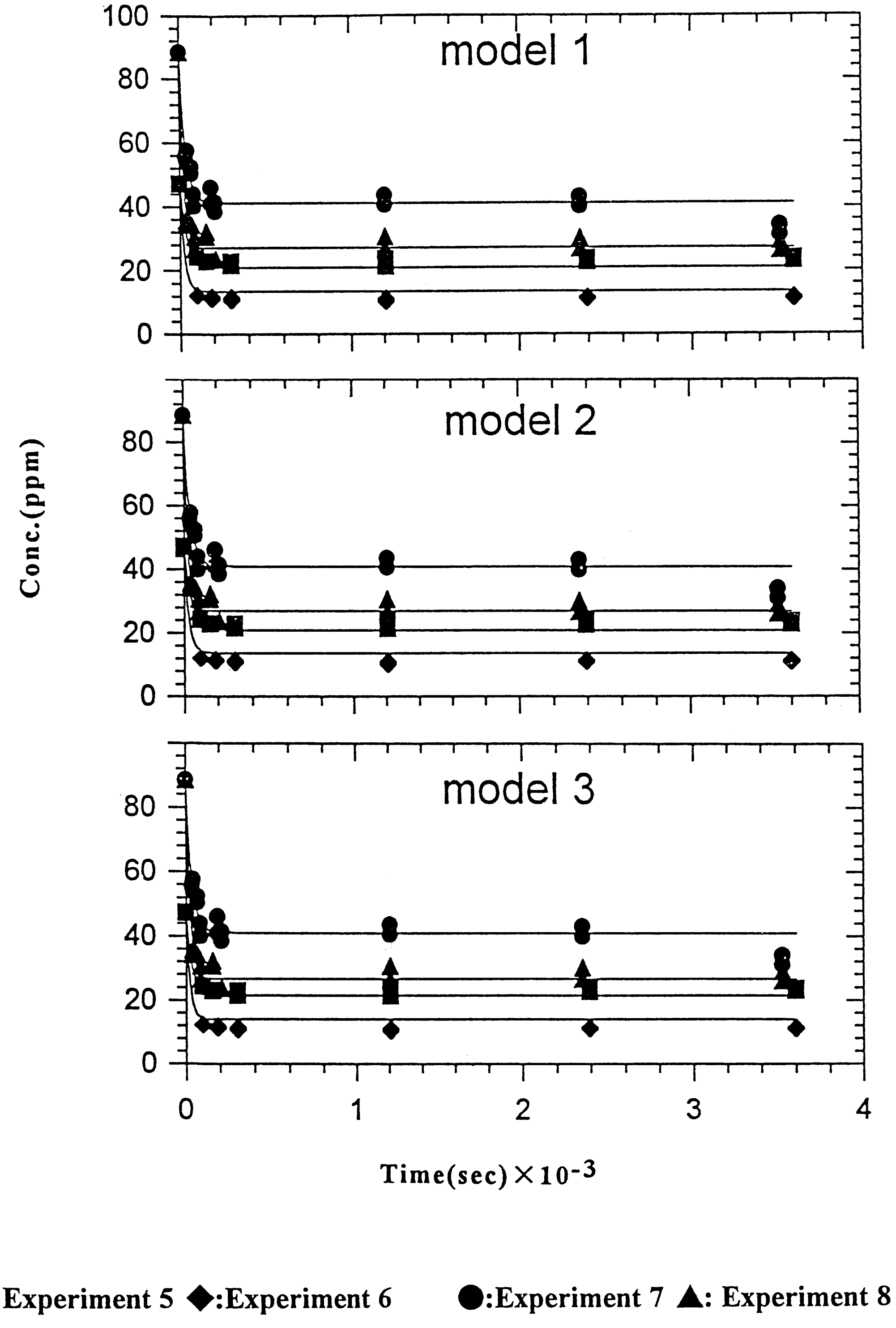


圖 5. 銅離子之不同濃度、不同土壤實驗數據合併，以三種模式模擬溶液中濃度隨時間變化情形……

Fig. 5. Combining different concentration of cadmium ions, different soil experimental data and using three models to simulate concentration of solution changes with time.

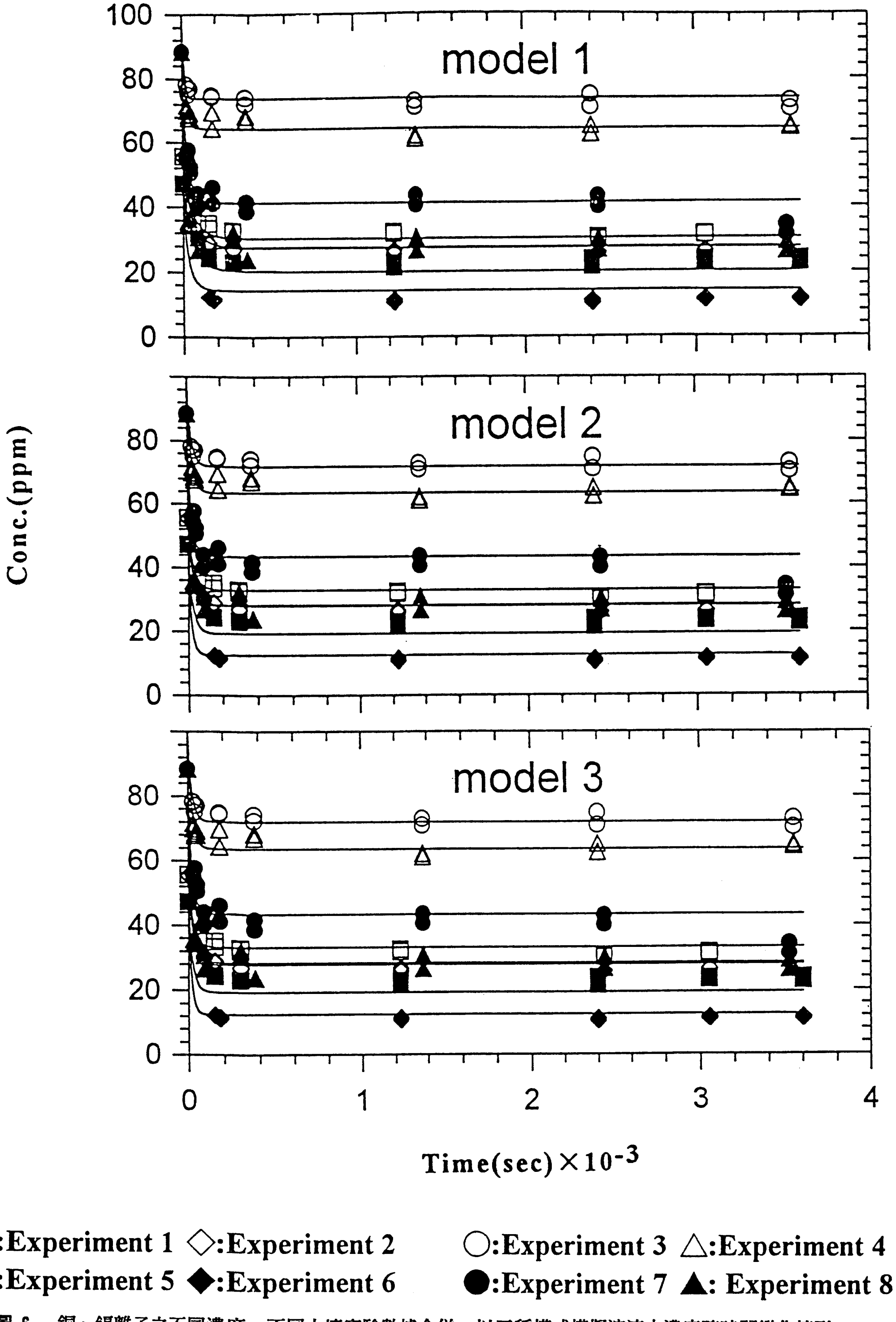


圖 6. 銅、鎘離子之不同濃度、不同土壤實驗數據合併，以三種模式模擬溶液中濃度隨時間變化情形……

Fig. 6. Combining different concentration of copper and cadmium ions, different soil experimental data and using three models to simulate concentration of solution changes with time.

參數。表 3 中所列參數之標準偏差雖已較小，95 %信賴區間仍包含 0。若先不考慮參數所代表的意義，由表 3 到表 4 可看出數據愈多，所得參數估值與之標準偏差愈小，至以八組數據估計所得之標準偏差與估計值比較已遠小於估計值，即其參數估值的準確性已提高。

比較求得之參數中的最大吸附量（R），各組數據分別求得之數值差距很大，即使爲同一組數據由不同模式所求出之值也不相同。與在平衡吸附研究中由平衡吸附模式 Langmuir isotherm 求得之最大吸附量比較，部分 R 值接近在平衡吸附研究時徵求之之總離子最大吸附量（Rtotal），部分 R 值接近單一離子之最大吸附量，另有少部份則在二者之間。

比較求得之參數中的 n 值，模式一與模式二以各組數據所分別求得之數值均接近 1。但以兩組以上數據合併後求得的數值，則銅離子以模式一在吸附力弱的土壤中所得之 n_3 較小，而在吸附力較強的土壤中所得之 n_2 較小。以模式二求得之 n 值均較大，尤以銅離子部分較明顯。

綜合以上所述，似乎各組實驗結果以不同模式之求得之參數值並無一定的趨勢，但相同土壤相同離子之數據合併後，所得數值較有規則。以三種模式所求得之最大吸附量均很接近，同時與將相同離子數據再合併，及全部數據合併後求得之結果也相近似，因此要得到穩定的最大吸附量，至少需要兩組不同條件的實驗數據。反應物級數（n）則至少需要四組以上不同反應條件的數據，而反應速率結言數（k）需要八組以上不同反應條件的數據，才能使所得的參數有意義。

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Application of Non-Linear-regression Method in the Determination of Parameters of Kinetic Adsorption Model of Heavy Metal in Soil[1]

Tsang-Sen Liu[2] and Chen-Fang Lin[3]

Summary

As the nonlinear adsorption model was often quoted in the study of phenomenon about solute transport and surface chemistry. Statistics and numetrical analysis, involved in the nonlinear model, were used in this research to inspect and minimize some errors might hidden in various conventional methods of parameter identification, for effectively regularizin greaction behaviors of system. Four kinds of red oxisols (fine, mixed, acid, hyperthermic paleusult), with diverse capacity of adsorption, were mixed with 50 ppm and 100 ppm Cu^{+2}/Cd^{+2} and measured the ion concentrations of Cu^{+2}/Cd^{+2} under inequilibrium state at different time during the adsorption process. With the aid of numerical analysis software to obtain the parameters of nonlinear differential eqaution, the required conditions for solution of the equation can be investigate, and the meaning of parameters can be identified, too.

All the curves derived from 3 models were representative and significant (>0.95). According to the pseudo 2 nd order adsorption reaction, some tests came out the fact that the maximum amount of adsorption was irrationally smaller than the observed one, it implied the pseudo 2 nd adsorption can not completely or ideally explain the phenomenon of adsorption between heavy meatal ions and soil. After the model modified by reaction order, the irrational situation above was eliminated.

Due to the rather high auto-correlation of data attained at different time under the same experimental codition, the derived parameters were coincident with the simulated ones, but the variance caused was too large to acquire the efficient parameters. Hence, to make the derived parameters meaningful, the maximum amount of adsorption derived from kinetic adsorption model should base on at least 2 sets of different concentrations, 4 sets of various conditions for reaction order (n), and more than 8 sets of different of coditions of reaction rate costants.

Key words : Parameter identification, Differential equation, Model.

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CONTENTS

The Relationship between Grain Productivity and Nitrogen-fertilizer Rate of Currently Cultivated Rice Cultivars II. The Effects of Different Nitrogen Rates on Volume Weight and Quality Traits in Rice
……………Ming-Hsing Lai, Chen-Chang Chen, Yih-Chuan Kuo, Chyr-Guan Chern, Chang-Pei Li, Tung-Hai Tseng and Ying-Chun Lin……1

Griffing and Hayman Diallel Analyses of Variance for Eating and Processing Quality Parameters of Milled Rice
………………………Yih-Chuan Kuo, Bill D. Webb and James W. Stansel…15

Comparison of Agronomic Characteristics and Chemical Composition among Different Hsian-tsao Strains (*Mesona Procumbens* Hemsl)
………… Min-Fu Hu, Huey-Ing Liu, Chien-Liang Chu and Sin-Yie Liu…32

Thermal Time Required for Fruit Development in Low-chill peaches
……………………………………………Chia-Wei Song and Shyi-Kuan Ou…42

Study on the Effects of Single and Mixed Sawdusts of Different Origins on hte Production of *Pleurotus Eryngii* …………………… Jin-Torng Peng…51

Assessment of Mushroom Waste (Sawdust) Compost as Muskmelon Seed-sowing Media……………………Ming-Hui Chang, Wei-Min Hsiang, Shiuan-Yuh Chien and Wei-Tin Huang…60

Composting Shiitake Sawdust Waste and Effects of Applied Composts on Growth of *Brassica chinensis* L. Makino
…………………………………Shiuan-Yuh Chien and Tzo-Chuan Juang…70

Application of Non-Linear-regression Method in the Determination of Parameters of Kinetic Adsorption Model of Heavy Metal in Soil
……………………………………… Tsang-Sen Liu and Chen-Fang Lin…82

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